US Army Corps
of Engineers
Construction Engineering
Research Laboratory

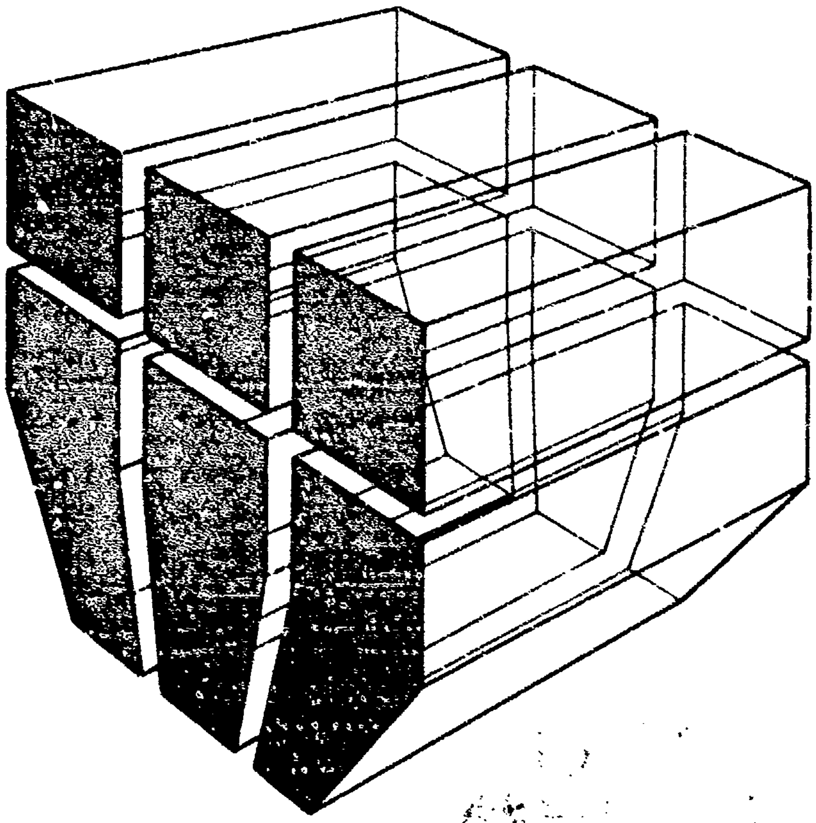
CERL

TECHNICAL REPORT N-160
April 1984

(12)

AD-A142 096

APPROPRIATE TECHNOLOGY FOR TREATING WASTEWATER AT REMOTE SITES ON ARMY INSTALLATIONS: PRELIMINARY FINDINGS



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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: CERL-TR-N-160	2. GOVT ACCESSION NO.: AD-A142096
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): APPROPRIATE TECHNOLOGY FOR TREATING WASTEWATER AT REMOTE SITES ON ARMY INSTALLATIONS: PRELIMINARY FINDINGS	5. TYPE OF REPORT & PERIOD COVERED: FINAL
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): E. D. Smith, J. T. Bandy, C. P. C. Poon, R. J. Scholze, S. R. Struss	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Construction Engineering Research Lab. P.O. Box 4005 Champaign, IL 61820	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 4A162720A896-B-043
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: April 1984
	13. NUMBER OF PAGES: 109
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are available from National Technical Information Service
Springfield, VA 22161

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

toilet facilities
composting toilets
aerated vault toilets

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

At U.S. Army installations, water lines and sewage facilities are provided only in the cantonment areas, where there are enough people and activities to justify sewage collection and treatment. At remote sites--e.g., guard stations, firing ranges, and training areas--four conventional methods have been used to treat human wastes: trenching and cat holing, pit latrines, vault toilets, and chemical toilets. With these approaches, however, there have been problems with odors, pollution, and operation and maintenance.

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This report provides information about the selection, installation, operation and maintenance, and costs of two alternative systems--composting toilets and vault latrine aeration. These systems have been used by the private sector and other state and federal government agencies. This report details early observation of system performance.

To determine the applicability of these two alternative technologies for Army use, the U.S. Army Construction Engineering Research Laboratory (CERL) is conducting field tests at Forts Leonard Wood, MO; Dix, NJ; Irwin, CA, and Jackson, SC. Until this field data and other information is collected, this report should be considered a "state-of-knowledge" document based on an examination of the literature and survey of operating systems.

FOREWORD

This work was performed for the Assistant Chief of Engineers under Project 4A162720A896, "Environmental Quality Technology"; Technical Area B, "Environmental Design and Construction Strategy"; Work Unit 043, "Design and Operation for Upgrading Wastewater Treatment Plants and Remote Site Waste Management." The technical monitors were Mr. W. Medding, DAEN-ECE-G, Mr. F. Bizzoco, DAEN-ECE-G, and Mr. R. Newsome, DAEN-ZCF-U.

The investigation was performed by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (CERL). Dr. R. K. Jain is Chief of EN.

COL Paul J. Theuer is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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APPROPRIATE TECHNOLOGY FOR TREATING
WASTEWATER AT REMOTE SITES ON
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1 INTRODUCTION

Background

At U.S. Army installations, water lines and sewage facilities are provided only in the cantonment areas, where there are enough people and activities to justify sewage collection and treatment. However, each installation has many remote sites--e.g., firing ranges, guard stations, and training and recreational areas. The Army now uses four conventional methods to treat human wastes at such sites: trenching and cat holing, pit latrines, vault toilets, and chemical toilets ("port-a-pots").

Trenching and cat holing are used when troops are on bivouac; waste is deposited in a small hole and covered with soil. However, other waste-handling systems must be installed when troops train on land that is not owned by the Army or when training areas are heavily used.

Pit latrines--large holes over which outhouses are built--can contribute to groundwater pollution; decomposing waste often causes odors near these units.

Vault toilets--outhouses over concrete chambers--are used most often for remote-site treatment on Army installations. These units give off foul odors caused by anaerobic decay--especially during warm weather. The stench attracts flies and other disease vectors, such as mosquitos. At many installations, these seats are no more than holes cut in a plywood board, making sanitation difficult. Maintaining vault toilets can be expensive and time-consuming. The waste must be pumped into a transport truck and properly disposed of; this can cost more than $200 a month for each unit. Cans, bottles, and ammunition thrown into the toilets often clog disposal hoses and must be removed by hand. When disposed of, the highly concentrated wastes can also be a shock load on the sewage treatment plant.

In chemical toilets, the outhouse and waste collection chamber are a single unit; chemicals control some of the odor from the stored waste. These toilets are particularly susceptible to vandalism because of their light fiberglas construction. According to the commander of one installation, "smelly, unsanitary, and...expensive" chemical toilets adversely affect the field training of his troops. Chemical toilets' maintenance problems and costs are similar to those for vault toilets. These costs may not seem extreme until one considers the number of vault and chemical toilets needed to meet an installation's requirements. One installation in the Midwest estimated in 1981 that approximately $60,000 yearly was spent on operating, maintaining, relocating, and pumping out the grease traps of 155 vault and 125 chemical toilets. This expense was confirmed by another Army installation that has 305 vault and portable toilets. (The updated cost for 1982 is more likely $75,000 to $100,000/year.) An Army installation in the Far west

estimates that it spends $80,000 per year on chemical toilets alone. Still another installation has estimated that its pumping and rental costs for chemical toilets amount to $170,000 per year.

One solution to these problems would be constructing sewered facilities at all remote sites; however, this solution is usually very expensive, due to the costs of supplying water to and transporting sewerage away from many widely separated sites. Even the option of providing a well and septic tank system at each location can be cost-prohibitive when ground water is not readily available or the soil is impermeable. Another problem is that a waterborne latrine facility must have freeze protection during the winter. Although the cost of constructing a waterborne facility can be high, it could be a viable alternative when improving sanitation and troop morale are high priorities. Costs depend on local condition, such as availability of water, soil type, and construction costs and must be determined individually. If a septic tank and leach field are being considered, local soil conditions and regulations for protecting ground water must be investigated.

Composting toilets and vault toilet aeration are two alternatives for remote site waste treatment which may meet the Army's requirements. These systems have been successfully used by the private sector and other governmental agencies (e.g., Department of Interior). The Office of the Chief of Engineers (OCE) has tasked CERL with evaluating these technologies to determine their applicability for Army-wide use.

Objective

The objective of this report is to study the problems associated with traditionally used methods of managing human waste at remote sites--pit latrines, vault toilets, and chemical toilets; and to analyze alternative remote site waste management technologies such as composting latrines and aerated vault toilets.

Approach

To accomplish these objectives, CERL conducted a survey of the literature as well as visiting and surveying private sector sites which use alternative on-site waste treatment technologies. On-site surveys of Army installations were made to familiarize CERL researchers/engineers with the problems of remote site waste management. Field tests of composting and aerated vault latrines were done at Forts Leonard Wood, MO, Dix, NJ, Irwin, CA, and Jackson, SC. Based on these experiences, interim selection/engineering guidance, cost estimates, and nonproprietary prototype designs were developed for composting latrines and aerated vault toilets. A final report will be issued once field testing and laboratory studies are completed. Until this final guidance is available, the Army will probably continue to construct traditional pit latrines and vault toilets. Consequently, this report also provides the best available information for pit/vault latrine and design and operation.

Mode of Technology Transfer

It is recommended that information from this study be incorporated as additions to Technical Manual (TM) 5-814-3, Domestic Wastewater Treatment; TM 5-814-8, Evaluation Criteria Guide for Water Pollution Prevention Control and Abatement Programs; TM 5-665, Operation of Sewerage and Sewage Treatment Facilities at Fixed Army Installations; and TM 5-666, Inspections and Preventive Maintenance Services, Sewage Treatment Plants and Sewer Systems at Fixed Installations. The information in this technical report also will be issued as an Engineer Technical Note.

2 COMPOSTING TOILETS

How Composting Toilets Work

Composting toilets were developed in Sweden and have been used for more than 30 years. Although most applications have been in private residences, their use in public facilities, such as National and State Parks, highway rest stops, and public beaches is increasing. It appears that composting, if given proper attention, can work even in public facilities where the typical user is not concerned with proper system operation.

Composting, the controlled decomposition of organic material into a humus end product, takes place by aerobic decomposition or anaerobic fermentation. In these processes, bacteria, fungi, molds, and other saprophytic organisms feed on organic materials, including human waste, and convert them to a more stable form.

Aerobic decomposition takes place very efficiently in the presence of oxygen. The process smells "earthy" and generates temperatures high enough to kill portions of its own microbial population, including enteric pathogens. In the absence of oxygen, anaerobic composting takes place slowly and produces putrid odors. A composting toilet is designed for continuous aerobic decomposition of human wastes. No water is used for flushing, so only night-soil (fecal matter, urine, toilet paper, and bulking agent) is introduced into the composting chamber.

Waste treatment by a continuous composting toilet relies on the natural process of decomposition, which requires 1 to 2 years. The process takes place in a large chamber beneath the toilet seat (Figures 1 through 4). This chamber is generally installed on a slope so that the waste slowly moves to a bottom removal area. Wastes are combined with sawdust, or other bulking agents, to form a mass that can be reduced into humus, and that continuously decomposes until disposed of. These bulking agents aid composting both physically, by loosening the pile for improved air diffusion, and biologically, by providing a carbon source for the aerobic bacteria.

Composting significantly decreases the volume of wastes, so the final amount to be disposed of is relatively small. For example, 8 cu ft (0.23 m^3) of compost must be removed annually from a continuous composter serving 15 people daily throughout a summer season. A vent pipe and fan constantly remove carbon dioxide, water vapor, and ventilation air from the chamber. Since most of the liquid is removed through evaporation, there is usually little danger that untreated wastes will reach groundwater or surface water. Table 1 describes various types of composting toilets; for detailed information, see Appendix A. Table 2 provides short answers to common questions about composting toilets.

Composting toilets are appropriate in areas where water is available but in short supply, and where electricity is readily available. However, they are best suited for areas without water. In these cases, composting toilets are probably the best alternative to vault toilets, pit latrines, and chemical toilets on Army installations.

Table 1

Types of Composting Toilets (Adapted from "Guide to the Composting Toilets," ECOS, Inc., 21 Emrie Rd., Boston, MA 02134)
(Metric Conversion Factor: 1 in. = 25.4 mm)

Type	Volume	Material	Price as of 1 May 83	Capacity	Electrical Requirements	Features
Clivus Multrum	Large volume	Fiberglas, Size: 45 x 101 x 79 in.	$5800-$8200, depending on accessories (not counting installation cost)	10-25 persons depending on number of midsections	Ventilating fan, 110AC-46W No electricity required with solar option	Produces nutrient-rich humus, no external power source necessary, insulated model available, no pasteurization of humus required ideal for new construction
Biological Toilet Model 75 and 75B	Medium	Fiberglass, Size: 36 x 40 x 36 in.	$1400-$1700 inclusive	2-4 persons (15 persons with [illegible]onal evapo[illegible])	Two fans 110V-46W; rotation motor, 110V-180W; heating element, 110V-1200W	Automatic mixing of waste to prevent compacting, internal heating elements, produces nutrient-rich humus, no pasteurization of humus required, ideal for new construction
Ecolet (same as Mullbank)	Small volume	Polystyrene (plastic), Size: 24 x 42 x 32 in.	$736 inclusive	3-5 pe[illegible]ons with occasional overloads	110V AC Transformer 110V Fan 42V-21W Heating element 42V-140W	Easy installation, internal heating elements, produces nutrient-rich humus, no pasteurization of humus required
Mull-Toa (Same as Bio-let and Soddy Potty)	Small volume	Polyethylene (plastic), Size: 21 x 30 x 28 in.	$795 inclusive	2-4 persons with occasional overloads	110V-AC 250W Two fans 2 thermostatically controlled heating elements. Automatic leveler	Automatic mixing of waste, built-in hygrometer to indicate humidity, easy installation, greatest weight reduction of waste of comparable models, lowest volume of air evacuated of comparable models (2.3 gal/sec), internal heating elements, produces nutrient-rich humus, no pasteurization of humus required
Bio-Loo	Small volume	Polyphenylenoxide (plastic), Size: 24-3/16 x 31 1/2 x 25-5/8 in.	$795 inclusive	2-4 persons with occasional overloads	Fan, 110V-23W; heating foil 110V 30W; pasteurization hot plate, 110V-160W	Pasteurization box heats waste and kills pathogenic bacteria, manually operated harrow to mix waste, easy installation, internal heating elements, produces nutrient rich humus
Biological Toilet Model A	Small volume	Polyethylene (plastic, Size: 22 x 41 x 31 in.	$980 inclusive	2-4 persons with occasional overloads	Fan, 110V-23W; drum rotation motor, 110V-115W; three heating elements, 300W (1200 opt.)	Automatic rotating drum mixes waste, easy installation, internal heating elements, produces nutrient-rich humus, no pasteurization of humus required

Table 2

Questions and Answers: Composting Toilets' Application to Army Installations

Question	Short Answer	Where Detailed Information Can Be Found in This Report
1. Where and when can composting toilets be used on Army installations?	At remote sites with no regular water supply and sewage facilities. When existing vault toilets or pit latrines are unsanitary. When water supply and sewage collection will not be provided soon. When no electricity is available at site.	Chapter 2, pp 12-37
2. Are composting toilets reliable in a variety of climates and under highly fluctuating loadings?	The system allows aerobic decomposition of organic waste and significant reduction of pathogenic organisms in the waste. The effectiveness increases with the temperature. Cold regions have very low composting rates. There the toilets serve more or less as waste containment units until the spring thaw allows composting to resume. The system can tolerate high fluctuations in loading as long as the recommended daily maximum load and the annual load are not exceeded. Good insulation, passive solar heating, and an external heat source can be used to increase the unit's effectiveness.	Chapter 2, pp 19-23, Chapter 3, pp 38-39. and Appendix A.
3. What are the appropriate criteria for selection?	Manufacturers recommend a specific number of uses, depending on temperature, for various sizes of composting toilets. Both maximum daily use and annual use should be within the allowable limits.	Chapter 2, pp 12-13, and Chapter 3, pp 38-44.
4. What is the cost?	A large toilet allowing 100 uses per day (at 55° to 65°F) (at 12.7°C to 18.3°C) costs about $6200, plus superstructure and installation. A small unit allowing 18 uses per day costs about $1125, plus superstructure and installation.	Chapter 3, pp 39-43.

Table 2 (Cont'd)

Question	Short Answer	Where Detailed Information Can Be Found in This Report
5. Are composting toilets easy to install and start up? What about site preparation?	Installing a large unit takes 32 man-hours, plus another 80 to 100 man-hours for superstructure installation. Site preparation and excavation could take 48 to 80 man-hours, depending on the local conditions. Experienced personnel can reduce the installation time somewhat. Manufacturers provide simple, specific instructions on start-up.	Chapter 3, pp 44-45.
6. What is the space requirement?	The largest unit with two seats plus one urinal measures 104-1/2 in. x 45-in. x 84-in. high (2654 mm x 1154 mm x 2133 mm). Another 8-in. (203 mm) minimum clearance above the unit is required. To minimize space and cost, the Army can design the superstructure to fit single or multiple composting units. Partial burial of the unit helps insulation and reduces the height of the entire facility.	Appendix A
7. What are the operational and maintenance requirements?	Daily addition of bulking agent. Monthly stirring of the pile. Semi-annual removal of compost	Chapter 2, pp 21-25.
8. What are the skill and manpower requirements?	Low skill; 1 man-hour/week-unit, including 10 man-minutes/day for adding bulking agent. Turning the pile takes 20 man-minutes/month. Removal of compost requires 2 man-hours twice a year.	Chapter 2, pp 21-25.

Table 2 (Cont'd)

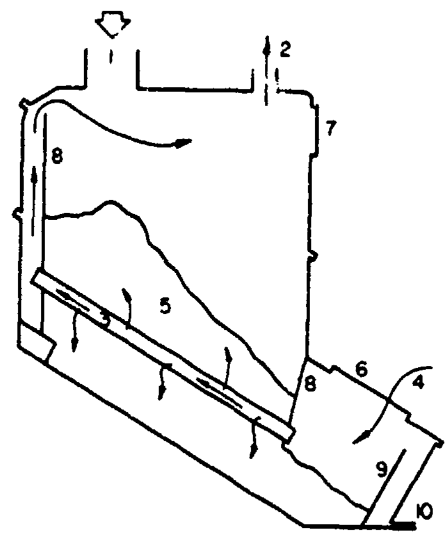
Question	Short Answer	Where Detailed Information Can Be Found in This Report
9. What are the system's limitations?	Inability to remove toxic and nonbiodegradable chemicals. Fire hazard if lit cigarette butts are thrown into the unit. Near freezing temperature stops the composting process; therefore, the unit capacity is used up faster, and the end product contains more organic and hazardous microorganisms than desired. Only accepts human waste and some kitchen waste. Greywater should be excluded. If these restrictions are observed and proper maintenance procedures are followed, no problems should be encountered.	Chapter 2, pp 29-30. Appendix A.
10. How does the composting toilet compare with other systems?	Superior to vault toilets, pit latrines, cat holes, chemical toilets, and recirculating toilets because the composting toilet is more sanitary and protects the environment better. Less expensive than pressure or vacuum sewer systems. Lower power consumption than aerated vault toilets.	Chapter 3, pp 41-44.

Table 2 (Cont'd)

Question	Short Answer	Where Detailed Information Can Be Found in This Report
11. What are the advantages/disadvantages of composting toilets?	Advantages: Provides more sanitary conditions and improved aesthetics for users without a wait for the development of the water and sewage systems in remote areas. Is simple to operate and maintain. Can be phased in according to budget availability. Conserves water. Has minimal to no energy requirement. Has low operating and maintenance costs. Disadvantages: High initial cost per troop, particularly in cold regions (more units required to contain the waste material because of the very slow composting rate). Possible odor, fly, and fire hazard problem with improper service and management. Residue must be removed carefully to minimize health risks. Users must not misuse the unit--e.g., trash, lit cigarette butts, and toxic chemicals must not be thrown in.	Appendix A, pp 65-81.
12. What is the energy consumption?	From 14 W per unit for the exhaust fan to 157 W per unit for both fan and heating system in some units. The power consumption is insignificant.	Chapter 3, pp 43-44. and Appendix A.
13. What are the opinions of composting toilet owners?	A survey of owners' opinions about composting toilets used in public facilities reveals favorable reaction in general. Owners are satisfied with the performance and the simplicity of operation and maintenance rerequirements. Most are aware that neglecting service and maintenance leads to odor and insect problems.	Appendix A, pp 81-85.

Table 2 (Cont'd)

Question	Short Answer	Where Detailed Information Can Be Found in This Report
14. What is the life expectancy of composting toilets?	Most manufacturers have a warranty period of 5 years for the unit --except fans, pumps or motors, which are generally guaranteed for 1 year. (In some facilities, pumps and motors are used to remove excess liquid.) The life expectancy of the Fiberglas unit is more than 20 years. Many composting toilet facilities in Europe have been used for more than 30 years.	Manufacturers' manuals cited in Appendix A.



The Arrows Indicate Air Flow Through the Toilet

Key:
1. Waste Chute
2. Vent Pipe with Fan
3. Air Duct
4. Air Intake
5. Composting Mass
6. Emptying Hatch
7. Inspection Hatch
8. Waste Baffles
9. Liquid Baffle
10. Liquid Drain

Figure 1. Composting chamber.

Size Selection

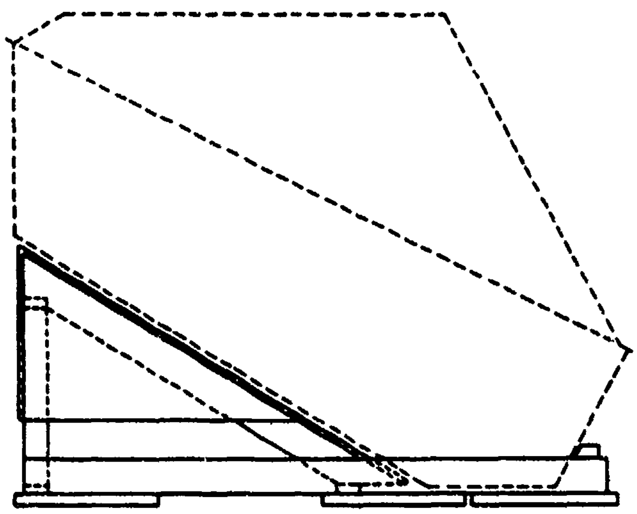
Large composting units are best for typical remote Army facilities; small units require more energy and maintenance and therefore would not be appropriate for most remote sites. If energy were available, small composting toilets could be used at a residential or continuously manned station that is very small (four persons or fewer), such as a guard station.

Factors Affecting Performance

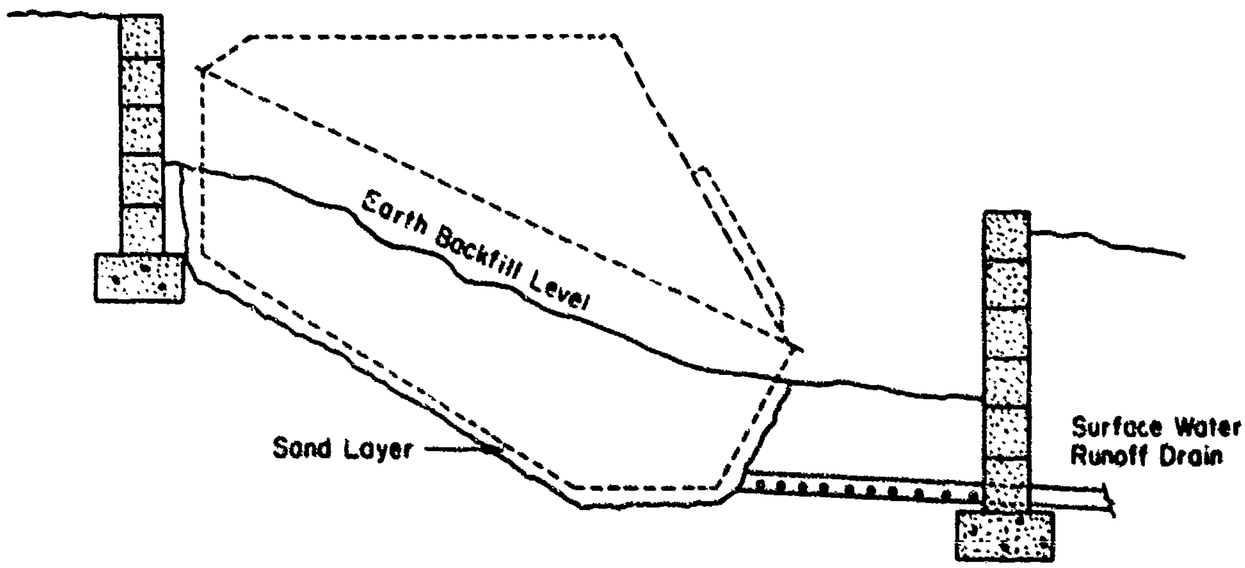
The performance of composting toilets at Army facilities depends on proper composting and efficient removal of excess liquid. Appropriate operation and maintenance is also critical.

Performance also might be affected by State and local regulations on composting toilets. Such regulations may govern the use of the unit itself, disposal of excess liquid, and ultimate compost disposal. The FE should find out whether these regulations apply to toilets installed at remote sites on Army posts.

After regulatory agencies have been contacted, the performance of the compost toilet in a specific situation must be considered. The following site-specific considerations affect the performance of composting units: climate, soil conditions, groundwater table, and availability of maintenance personnel, energy, and water.



Wood Support on Concrete Paving Blocks



Earth Support for Below Grade Installations

Figure 2. Wood and earth supports (from "Clivus Multrum Health Considerations," Planning, Installation, and Operation Manual for Public Facilities.)

GENERAL
MAINTENANCE INSTRUCTIONS
FOR
MILITARY INSTALLATIONS

I. ADDITION OF BULKING AGENT

Once a day (or approximately every 100 uses) add to each toilet chute about 1/2 gal (1.9 L) of sawdust, lawn clippings, peat moss, shredded leaves, or wood shavings (not chips).

Every month, inspect the height of the waste pile through the waste access door on the front of the tank. If the air channels are exposed, add enough bulking agent to cover them. If the waste appears to be piling up and clogging the toilet chutes, then rake over the waste until it is evenly distributed. The waste pile should be moist with a crumbly texture. If it appears to be compact, increase the amount of bulking agent, but not more than double the amount indicated above.

II. MOISTURE CONTROL

Each month, visually inspect the waste pile through the waste access door. If the pile seems dry, especially towards the front (near the door), then water the pile for about 5 minutes with a hose having a spray nozzle. Repeat this daily until water appears in the liquid end-product chamber at the very front of the tank's bottom. If the pile seems too wet, add bulking agent each week until the pile seems moist and crumbly.

III. VENTILATION

Every 3 months check the draft by holding a blown-out match near the edge of the toilet seat while lifting the lid slightly. The smoke should be drawn into the toilet. If not, check the fan or clean the vent stack.

Check the ventilation further by holding a blown-out match near the air inlets on the end-product access door on the front of the tank. If the smoke does not enter the tank, open the end-product access door and check to see if liquid or compost is blocking the triangular air duct openings in the front baffle. If so, clean the openings.

IV. REMOVAL OF LIQUID AND COMPOST

If liquid is drained or pumped automatically to a leach line or to a greywater system, there will be no maintenance other than keeping the drain line clear and the pump operational.

Under no circumstances should the liquid be allowed to accumulate high enough to cover the air intakes in the end-product chamber. If liquid level rises, unclog screen in liquid baffle.

Once a year, check the end-product chamber for accumulation of compost. Always leave approximately a 10-in. (254 mm) layer on the bottom. About 2 bushels (0.06 m^3) will have to be removed after the firs year, during which no compost will appear.

Figure 3. Clivus Multrum's sample instructions for servicing composting toilets on military installations. (Information for this figure was obtained through personal communication with Clivus Multrum, USA, Inc.)

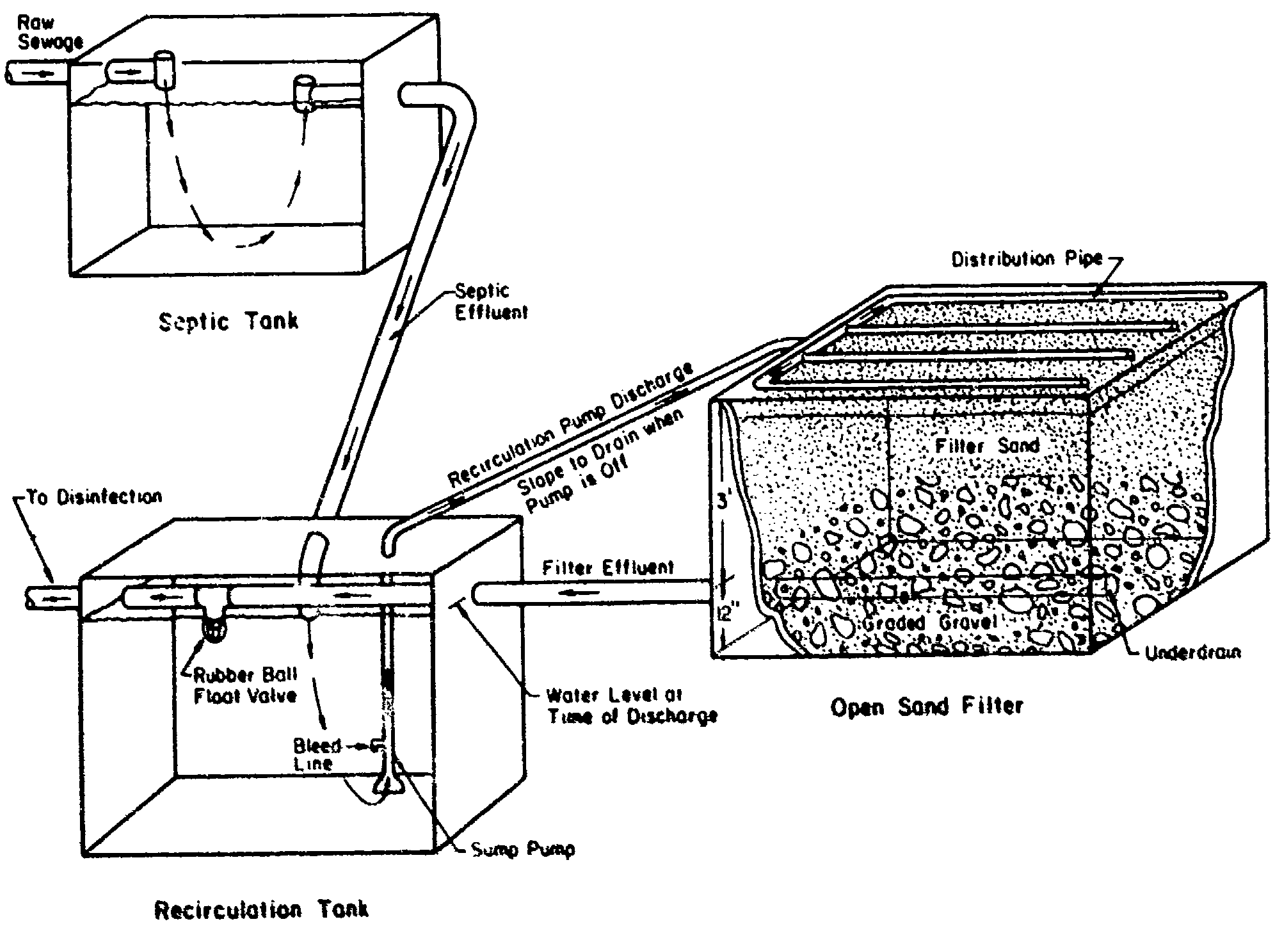


Figure 4. Septic tank-recirculating sand filtration system. (From M. G. Teske, "Recirculation--An Old Established Concept Solves Some Old Established Problems," paper presented at the 51st Annual Conference of the Water Pollution Control Federation.)

Proper composting depends on temperature and adequate ventilation. In colder climates, the composting chamber may have to be insulated to maintain adequate composting temperatures. Otherwise the toilet serves only as a storage chamber. In extremely cold climates, it may even be necessary to install a heating system. If the structure is positioned so that it receives as much sun as possible, solar glazing might provide enough heat. Solar glazing is recommended whenever a unit is to be used through the winter months (except in warm climates).

In addition to supplying a continuous flow of air to the compost pile, adequate ventilation reduces odors and decreases moisture buildup. The amount of moisture that can be removed depends primarily on the climate (temperature and humidity). To ensure adequate ventilation, Clivus Multrum recommends, as a minimum, a wind-operated turbine mounted on the vent stack. A fan operating continuously is preferable. Fans usually need electricity, but direct current (DC) or solar units may be used when no alternating current (AC) power is available (see Ventilation).

Operation and Maintenance Requirements

General Principles

A composting toilet is a large chamber into which wastes and organic bulking agents are placed for biological and physical breakdown into humus material by aerobic decomposition. Breakdown (or treatment) of the wastes occurs naturally, without additional water or chemicals, by aeration, using a series of air channel and baffles and a continually operating fan (see Figure 1). The organic bulking agents (e.g., grass clippings, leaves, sawdust, finely chopped straw) provide a source of carbon for the organisms which treat the waste, and also keep the pile loose for proper air distribution. The addition of bulking material is essential for proper operation of the unit. Investigation indicates that bulking material should be added at the rate of 1 cu ft (0.03 m^3) for every 200 uses, although this is site-specific and the manufacturer's guidance should be followed. If the facility is used every day, it is advisable to add bulking material at least every other day. The material can be added either by a contractor, or by troops during routine latrine maintenance. The only other maintenance required is semiannual removal of the compost product. If proper composting has occurred, the humus material should be safe to handle. However, it is recommended that this material be handled carefully and disposed of in a landfill to prevent transmission of diseases. See section on Handling and Disposal of Compost.

Clivus Multrum recommends the following operation and maintenance procedures:

1. Keep the toilet seats closed when not in use.

2. Keep the pile moist (check every 2 months).

3. Remove the liquid end product (inspect each month or after every 1000 uses).

4. Add 10 quarts (9.46 L) of bulking agent every other day or 1 cup (236 cm^3) per use (based on 75 to 100 uses per day).

5. Remove the compost as needed (after 1- to 2-year start-up period, up to 2 bushels of compost may have to be removed annually).

6. Maintain the ventilation system (remove fan and clean vent stack once a year).

7. Prohibit smoking and fires near the units.

8. Maintain proper temperatures.

9. Inspect the tank support every year.

10. Clean the toilet chute and urinal properly. (Use a mild detergent--not toxic chemicals that could interfere with the composting process.)

11. Check for odor once a month. If odor is present:

    a. Check the fan

    b. See if the seat closers are operating

    c. Check for excess liquid buildup

    d. Make sure the bulking agent is reaching the pile (not accumulating directly under the chute).

12. Rake the pile if all the above are in order but there is still an odor.

According to Clivus Multrum, if carbonaceous matter cannot be added every other day, but must be added in larger quantities less frequently, then it should be "raked in" to the pile to ensure the proper carbon-nitrogen ratio throughout the pile.

For Army installations, some of these suggestions probably will be unnecessary. For example, with anticipated heavy urine loading, the pile will alway be moist. Draining excess liquid to a dry or leach field makes it unnecessary to manually remove the liquid end product.

Pile Moisture

Moisture in the pile depends on urine loading, rate of air ventilation, and quantity and frequency of bulking agent addition. Under normal use and with daily addition of a bulking agent, most owners of Clivus Multrum composting toilets have to add moisture to the pile occasionally. Army installations, on the other hand, may find excess liquid in the pile because of heavy urine loadings; increasing the ventilation rate or adding bulking agent may

solve the problem.* However, the additional ventilation capacity needed for Army applications is not known now. By trial and error, more bulking agent can be added daily; the pile can be turned more often (e.g., once a month) to increase moisture evaporation.

With high urine loadings, excess liquid flows to the liquid storage compartment, from which it can be drained by gravity or pumped from the composting toilet. The liquid should not be allowed to accumulate so that the air ducts in the pile are blocked. If this happens, increasing the fan's size or adding more bulking agent will not help, since air cannot enter the pile. Consequently, anaerobic decomposition will take place, and the unit will not perform as designed.

The excess liquid can be handled in two ways. It can be stored in a collection chamber and pumped out periodically for treatment elsewhere. Another approach is to provide a subsurface adsorption system or a leaching field for disposal of the liquid. A percolation test will indicate the soil's suitability for subsurface adsorption and the appropriate application rate. Table 3 can be used as a guide. For example, it suggests that soil having a percolation rate equal to or less than 1 in./60 min (10 mm/24 min) is unsuitable for a leaching system. A large Clivus Multrum unit produces up to 10 gal (37.9 L) of liquid per day according to the manufacturer. Even if three times that amount is assumed for Army application, under the least desirable percolation condition (0.45 gpd/sq ft) (4.18 Lpd/m^2), the surface area required for a leaching field is 30/0.45 = 67 sq ft (6.2 m^2). Assuming every linear foot (0.3 m) of trench provides 3 sq ft (0.28 m^2) surface area of absorption, a 22-ft (6.7 m) leaching trench would meet the Army's needs under the most severe conditions.

When the percolation rate indicates that the soil is unsuitable for subsurface disposal, a mound system can be used. Only a small amount of soil is needed for a 22-ft (6.7-m) long trench of the mound system; the associated cost should be less than $250. However, if the composting unit is below grade, the excess liquid may have to be pumped to the mound system.

Installation

To assess installation, operation and maintenance of composting toilets, CERL has set up demonstration projects with seven large composting toilet units (two toilets and one urinal). Refer to Chapter 5 for more information. Field tests are being performed at Forts Dix, Irwin, Leonard Wood, and Jackson.

General Principles

To install large composting toilets, some excavation and foundation work may be required. A Clivus Multrum unit can be seated on a wooden rack placed on a concrete pad or on several concrete paving blocks. The toilet can also

*Improper addition of peat moss could lead to channeling, which in turn could cause liquid to accumulate without being treted in the storage chamber.

Table 3

Sewage Application Rates
(Metric Conversion Factors: 1 in. = 25.4 mm; 1 gpd/sq ft = 42 Lpd/m^2;
1 ft = 0.30 m)

Time for Water to Fall 1 in. (min)	Allowable Rate of Settled Sewage Application (gpd/sq ft) USPHS[a]	USEPA[b]	GLUMR[c]
<1	5.0[d]	b	1.2
1	5.0[d]	1.2	1.2
2	3.5[d]	1.2	1.2
3	2.9[d]	1.2	1.2
4	2.5[d]	1.2	1.2
5	2.2[d]	1.2	1.2
6	2.0	0.8	0.9
7	1.9	0.8	0.9
8	1.8	0.8	0.9
9	1.7	0.8	0.9
10	1.6	0.8	0.9
11	1.5	0.8	0.6
12	1.4	0.8	0.6
15	1.3	0.8	0.6
16	1.2	0.6	0.6
20	1.1	0.6	0.6
25	1.0	0.6	0.6
30	0.9	0.6	0.6
31	0.8	0.45	0.5
35	0.8	0.45	0.5
40	0.8	0.45	0.5
45	0.7	0.45	0.5
46	0.7	0.45	0.45
50	0.7	0.45	0.45
60	0.6	0.45	0.45
61-120	e	0.2	e
>120	e	e	e

Note: The FE should follow State and local regulations.

[a]Manual of Septic-Tank Practice, HS Pub 526, III W (Washington, DC, U.S. Public Health Service [USPHS], 1967).

[b]Design Manual Onsite Wastewater Treatment and Disposal Systems (Cincinnati, Ohio: U.S. Environmental Protection Agency [USEPA], October 1980).

[c]Recommended Standards for Individual Sewage Disposal Systems (Great Lakes-Upper Mississippi River Board of State Sanitary Engineers [GLUMR], 1980 Edition).

[d]Reduce rate of 2.0 gpd/sq ft where a well or spring water supply is downgrade; increase protective distance, and place 6 to 8 in. sandy soil on trench bottom below gravel and between gravel and sidewalls.

[e]Soil not suitable.

be half buried in a tightly packed earth and sand bed.[1] Soltran units should be on concrete pads; they cannot be partially buried. This is because the Soltran composting tanks need to be replaced from time to time.

The large composting toilets are fairly heavy when filled to capacity. For example, the largest unit (a Clivus Multrum with two midsections) weighs 3000 lb (1361 kg) with waste and peat moss bed material. Installing the large composting toilets at remote sites with different soil types and densities presents few problems, however, because the support area of the tank's floor is quite large (26 sq ft or 2.4 m^2).

Cost estimates for the two methods of composting toilet support are as follows:

1. On concrete pad with wooden rack:

48 hours of labor @ $14.00/hr...........	$672.00
Excavation, material....................	120.00
Total...................................	$792.00

2. Partially buried on tight soil and sand layer with two concrete block retaining walls:

Labor and excavation together...........	$594.00

These costs are for tank support only; building support will be additional. Figure 2 shows schematics of these methods. The above conditions assume a topography with a slope of approximately 30 degrees, so little excavation is required. If the topography is not ideal, or if the composting toilet building must be kept low, a deep hole has to be dug to install a large unit. The excavation and the deep retaining walls required increase the installation cost significantly. For the first unit at Fort Leonard Wood, it cost $2500 to excavate an 8-ft (2.4-m)-deep hole and to install a concrete footing and retaining walls on three sides of the hole. At Fort irwin, the building was supported on telephone poles set into the ground around the composting tank. The open area beneath the building was ther enclosed using exterior siding. This system cost about $800 to construct.

Clivus Multrum estimates that installing the composting unit would take local contractors 32 man-hours--this includes assembling the unit on site, placing and securing on the support, and installing the fan and ventilation system. Clivus Multrum personnel need about 16 man-hours. The typical minimum cost of installation quoted by Clivus Multrum is $500 (1982 dollars); this does not include the cost of a prefabricated structure to house the toilets. CERL's field experience indicates that contractors take about 48 man-hours to install a unit. The prefabricated structure requires another 20 to 30 man-hours for installation. The total installation cost varies from $5000 to $7000 for site preparation, foundation work, assembly of composting toilet and superstructure, and electrical work. Installation of multiple toilets can reduce the cost per unit to between $3000 and $5000, depending on the type of

[1] _Manual for Planning, Installation, and Operation and Maintenance_ (Clivus Multrum, USA, Inc., 1981).

foundation used and local conditions. For total costs, see the Selection and Cost Estimate section, pp 38-45.

Ventilation

Ventilation supplies oxygen to the composting chamber. This is necessary for the aerobic composting process and for the evaporation of excessive moisture in the composting pile. Most composting units are ventilated by a natural draft assisted by an in-line fan. Clivus Multrum, for example, provides a 110-V, 30-W, alternating current (AC) fan, where AC current is available. If necessary, a 12-V, direct current (DC) fan can be substituted. It can be powered by a solar package, which consists of solar panel, storage battery, and controls. This system is designed to operate the fan continuously, regardless of weather conditions.

The use of a wind turbine ventilator mounted on a vent stack is not recommended at this time. During the periods of low winds, insufficient oxygen will be supplied to the waste to insure proper composting.

Solar Glazing

To maintain the proper temperature for composting in cold climates, the toilet ideally should be installed inside a warm house so heated air can be drawn into the unit for ventilation. When this is impossible--at remote areas on Army installations, for example--solar glazing can be built into the tank enclosure to aid composting on cold sunny days (see Figure A1 of Appendix A). The SOLTRAN system specializes in solar-heated superstructures with either small composting toilets for home use or large composting tanks for public facilities (see Appendix A). Solar glazing can be built into any large composting toilet enclosure.

Start-up

To start the composting process, a layer of thoroughly moistened peat moss must be packed tightly into the bottom of the composting chamber. Twenty cubic feet (0.57 m^3) of tightly compressed peat moss will be needed for a large composting toilet. One cup (29.6 cm^3) of liquid dishwashing detergent added to 50 gal (190 L) of water can be used to moisten the peat.

On top of the peat, a 2-in. (50-mm) layer, or about 3 cu ft (0.09 m^3), of garden topsoil or forest leaf mold is spread; this introduces organisms which will promote decomposition.

During the first year of operation, there may be problems with insects, particularly flies, which are introduced with the soil and leaves. These pests can be controlled if a small amount of a biodegradable Rotonone-base or Pyrethrim-base insecticide is applied to the surface of the pile. Insecticide strips can also be hung in the composting tank.

Acceptability of Composting Toilets

While trenching, cat-holing, and pit latrines must be used in some remote training areas for proper simulation of field conditions (training realism), vault and portable toilets (chemical or nonchemical) can be replaced by composting toilets (where applicable). This will eliminate offensive odors, insect infestations, highly unsanitary conditions, and contamination of the surrounding areas with human wastes. Consequently, the general welfare of Army personnel is upgraded, while at the same time, the environmental impact is reduced.

A CERL survey indicates that owners of large composting toilets are generally satisfied with the units (Appendix A). Most of these owners are park service installations interested in providing a sanitary and acceptable toilet facility to park visitors and in protecting the environment from water pollution. Properly installed and maintained, composting toilets can meet these same objectives on Army installations. At Fort Leonard Wood, for example, Army personnel are accepting the unit much more readily than they do the existing chemical and vault toilets.

It should be emphasized that composting toilets must be maintained properly. In many cases, installations may be able to contract for services such as inspection, addition of bulking agent, and periodic removal of composted material (twice a year beginning 1 to 2 years after start-up). With proper instruction and training, however, troops can handle maintenance (at minimum, the addition of bulking agent). Everyone who does this work must be familiar with the toilet's design and standard operating procedures. Without proper maintenance, a composting toilet will eventually become a very expensive vault toilet with the same unsanitary, unacceptable conditions. It is imperative that someone has the responsibility and is held accountable for the day-to-day operation and maintenance of the composting toilets. Perhaps range control personnel should have a checklist and responsibility or perhaps the same individual who is contracted through the DEH office to pump out chemical toilets and vault toilets should be given the responsibility.

Service and Management of Composting Toilets

The literature survey and the information provided by composting toilet owners* indicates that proper service and management of composting toilets in public facilities are very important to reliable operation. Table 4 lists complaints about composting toilets and suggests the causes of the problems. Three basic steps can be taken to correct these difficulties:

1. Follow the manufacturer's operation and maintenance manual.

2. Train the personnel who service and manage the composting units.

3. Provide instructions to users and obtain user cooperation.

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*U.S. Department of Agriculture Forest Service, U.S. Environmental Protection Agency, California State Department of Health, and the Appalachian Mountain Club.

Table 4

Problems With Composting Toilets

Complaints	Causes
Odor	Liquid accumulation. Insufficient aeration through the composting pile (toilet seats left uncovered; wind turbine or solar chimney do not provide enough draft; waste pile not turned or mixed). Toilet chute not properly cleaned periodically.
Insects	Toilet seats uncovered. No screen for window and door. Toilet use before the proper ecology is established in the waste pile. Introduced with starter or bulking agent.
Fire and explosion hazard	Cigarettes and ashes thrown on a waste pile that is too dry because of excessive draft or too much bulking agent. Solvents and explosive chemicals thrown in. Anaerobic decomposition allowed, generating methane gas (see causes of odor, above).
Unit fills up too fast (insufficient composting)	Cold temperatures slow composting process significantly (not enough insulation of the composting unit; mass of waste pile insufficient to maintain the temperature in the pile). Toxic materials added inhibit bacterial action. Foreign objects added that are not biodegradable --e.g., metal, glass, plastics. Unit receiving too high a use.
Risk in handling composted material	Improper addition of bulking agent. Composted material removed too soon. Insufficient air supplied to waste pile.

Manufacturer's Operation and Maintenance

Every composting toilet manufacturer provides operation and maintenance manuals. Following the instructions can help ensure long-term proper functioning of the unit. In addition, composting toilets on Army installations may have to be serviced with special care because of heavy year-around usage pattern. Since the Army does not have long-term experience with these toilets, the guidelines below are based on information about composting toilets operated by other public and private agencies in various parts of the United States.

Although composting toilet units for public use have a large containment capacity, periodic overloading can be expected. This will lead to a short circuit of fresh waste to the "composted" section, liquid accumulation, improper mixing, and related problems. The Appalachian Mountain Club (AMC), Gorham, NH, has several years of highly successful experience with composting

toilets at remote locations in the White Mountains. As a result, AMC has developed detailed guidelines for maintaining and troubleshooting large composting toilets.

The most important service suggested by AMC is raking the waste pile every 6 to 8 weeks. Composting toilet manufacturers do not emphasize this service enough; for example, Clivus Multrum recommends raking the waste pile only when odors develop. Raking the pile mixes and aerates the material, reduces excessive moisture, and provides active microorganisms access to fresh waste material. This simple step can eliminate most problems in the operation of composting toilets.

For proper management of the SOLTRAN system, which requires rotation or replacement of the composting tanks from time to time, accurate records about installation and use are essential. If a number of people are responsible for maintaining any composting toilet, records of use and maintenance are useful to insure that tasks are completed on schedule. Figure 3 shows general servicing instructions prepared by Clivus Multrum for military installations. All manufacturers of large composting toilets recognize the problem of liquid accumulation. Using a leach line or pumping out the liquid is normally recommended. A 10-ft (3-m) leach line is adequate for the largest Clivus Multrum unit--as long as the surrounding soil has sufficient adsorption capacity (see Table 4). (The uncertain quality of the drained liquid requires further study.)

Training of Service Management Personnel

Personnel must be trained to service and manage composting toilets properly. Visits to sites with operational composting toilets would give Army personnel first-hand experience with the units.

The demonstration projects recently started at Forts Leonard Wood, Dix, and Irwin provide other opportunities for training. It should be noted, however, that a new composting toilet behaves differently from one that has been used for several years. A new unit tends to have marginal composting, and problems with flies, odor, and underaeration or overaeration during the first year. Operation of the six units now installed on Army installations should provide valuable information for future planning of composting toilets.

Training should start as early as possible--preferably during the design stage. The Army designer should emphasize to personnel the importance of proper service and management. Operation and maintenance requirements should be detailed in an Army Regulation to properly work composting latrines into the system. A service schedule and a method of record keeping should be established before start-up, and can be revised as needed.

Instructions to Users and User Cooperation

Composting toilets will fail if used carelessly. It is important, then, to give users some basic rules to follow. An instructional poster on an inside wall of the unit works well because users can be reminded conveniently and repeatedly.

The following instructions are most important:

--Close the lid of the toilet seat after use. An open lid will restrict the air flow through the pile, leading to anaerobic conditions. Self-closing lids are available.

--Do not throw in lit cigarette butts.

--Do not throw trash down the chute.

Handling and Disposal of Compost

Removing, handling, transporting, and disposing of compost should be done carefully; direct contact should be avoided. Color and odor of the processed material do not indicate reliably whether the waste is composted. There may be pathogens even in a black and odorless end product. Rubber gloves and a face mask should be worn whenever handling the compost, and washing with a disinfectant soap afterwards should be practiced to prevent contracting diseases.

The simplest means of compost disposal is shallow burial. Massachusetts, for example, recommends a 6-in. (152-mm) minimum cover. Some states require sanitary landfill disposal; others do not specify how compost should be disposed of and allow it to be spread on open ground. Controlled burning is too costly to be an acceptable alternative, and open burning is outlawed in most states. The recommended practice is to transfer compost in sealed plastic bags and dispose of it in a sanitary landfill.

Although these precautions might appear to be extreme, they are no more stringent than what is recommended whenever human wastes, treated, or untreated, are handled. No matter how completely the wastes have been degraded, there is some probability of pathogenic organisms like viruses surviving, so the wastes should be handled cautiously.

If properly maintained, composting toilets should present no health hazard to the user or to the person adding bulking agent. The only hazards are those associated with handling the wastes and compost within the composting chamber itself. By contracting out the internal maintenance tasks, much like the pumping of vault toilets is now handled, the health risks will practically be eliminated, since trained specialists will be the only ones handling the wastes. Contracted maintenance would also help to ensure regular inspections and standardized procedures. Addition of bulking agent, along with regular latrine maintenance, such as cleaning toilets and restocking toilet paper, remain the responsibility of the using troops. A Health Hazard Assessment is being conducted by the Army Office of the Surgeon General and the U.S. Environmental Hygiene Agency. The assessment is collecting data comparing composting toilets, vault toilets, pit latrines, chemical toilets, and aerated vault toilets.

Composting Toilets and Greywater Disposal System

Most installations will not extend a wastewater collection system to remote sites because this is extremely costly. However, extending a piped water supply system is much less expensive and could be done in the near future. When plenty of water is available, flush toilets can be used and wastewater can be collected from various other activities at the site. Many on-site treatment systems can be considered, including septic tank-leaching field, septic tank-recirculating sand filtration, and evaporation lagoon. But should composting toilets be provided now if a piped water supply and other on-site treatment systems may be installed in the future?

The answer is yes--if the following conditions are met:

1. The composting toilets will be used with the greywater treatment system.

2. Regulating agencies will allow a reduction in the size of an on-site treatment system used with composing toilets.

Sanitary conditions can be improved immediately at remote sites that meet these criteria. Composting toilets could be installed immediately, and then when a piped water supply becomes available and greywater is generated, only a simple treatment system will be needed. This is better than waiting to improve sanitary conditions until a collection system can be installed and the treatment plant expanded. Water conservation is a significant advantage of using composting toilets with a greywater treatment system. Flushing toilets takes about one third of the water used in an average household.

Greywater without toilet waste can be treated by various simple methods. When soil conditions permit sewage percolation without contamination of the groundwater near the site, one of the following systems can be used: (1) a septic tank with a seepage pit, seepage trench, leaching bed, or leaching mound; or (2) a seepage lagoon.

The septic tank--though not an absolute requirement since composting toilets remove much of the sewage solids--can serve as a holding tank so that the supernatant can be applied to the seepage or leaching unit at a more uniform rate. Most states allow a 20 to 50 percent reduction in the size of such on-site treatment systems when composting toilets are used, since the wastewater carries lower hydraulic biochemical oxygen demand (BOD) and suspended solids (SS) loads.

There are only two alternatives when soil conditions are not suitable for underground discharge and no surface discharge at the site is possible: evaporation lagoon (lined) and septic tank-evapotranspiration bed. These on-site systems can be used only when the evaporation rate exceeds the sum of precipitation and the rate of wastewater application.

The septic tank-recirculating sand filtration system can be used when soil conditions are not suitable for underground discharge but surface discharge at site is possible. Traditionally, intermittent sand filters have been used to improve the quality of septic tank effluents. However, every time the septic tank effluent is dosed on the sand filter surface, a

considerable odor develops. A recirculating sand filter developed by the Illinois Environmental Protection Agency (EPA) can eliminate the problem.

The system consists of a septic tank, followed by a recirculation tank, and then an open sand filter (Figures 4 and 5). The pumping system has time clock control mechanisms to regulate recirculation; fresh liquid is dosed on the surface of the sand filter, thus eliminating any odor. Float controls override the clocks when overflow is imminent but it is not time for the pumps to operate. The following design standards should be used for the recirculating filter:

Sand size: 0.3 to 1.5 mm (effective size), preferably 1.5 mm size. The uniformity coefficient should be less than 3.5.

Dosing rate: 3 to 5 gal per square foot filter surface per day (122 to 203 $L/m^2/day$), based on raw sewage flow; 3 gal/sq ft/day (122 $L/m^2/day$) is preferred.

Recirculation rate: 3:1 to 5:1, with 5:1 preferred.

Dosing controls: Time clock with float shut-offs and high-level override.

Dosing pumps: Should have capacity to empty recirculation tank in 20 minutes or less.

The Illinois EPA has developed design criteria for the dosing tank and sand filter. The volume of the dosing tank should be large enough so that during the dosing cycle, the sand filter will be soaked to a 2- to 4-in. (51- to 102-mm) depth. The pumps should evacuate the chamber in 15 to 20 minutes. Duplicate pumps should be provided and cycling controlled by a time clock with control override. The sand filter's underdrains should be 8 to 10 ft (2.4 to 3.1 m) apart with 12 in. (305 mm) of graded gravel bedding covering them in 3- to 4-in. (76 to 102 mm) layers. These layers should be 1-1/2 to 3/4 in. (38 to 19 mm), 3/4 to 1/4 in. (19 mm to 6.4 mm), and 1/4 to 1/8 in. (6.4 mm to 3.2 mm) diameter (Figure 5). Sand should be placed on the gravel to a 24-in. (610 mm) depth. The sand should be 0.3 to 1.5 mm in diameter. The larger size is preferable; the uniformity coefficient should not be more than 3.5. Dosing should be as even as possible; troughs should be no more than 10 ft (3.1 m) apart.

The day-to-day operation and maintenance requirements of the recirculating sand filter are minimal. The sand surface must be raked once a week. The distribution troughs must be kept level and the openings clean to allow even distribution over the sand surface. The sludge level in the septic tank must be kept below the overflow level so that solids are not carried over. The pumps and floats must receive some routine maintenance and cleaning. Experience has shown that an average of 1 to 2 hours of operation and maintenance each day at an installation with a design capacity of 40,000 to 50,000 gpd (150,000 to 190,000 Lpd) will ensure good treatment. Daily maintenance is not absolutely necessary for smaller systems.

When properly designed and operated, the system produces excellent effluent quality. Table 5 lists results from the monitoring of 12 typical recirculating sand filter systems in Illinois; included were sewage treatment plants,

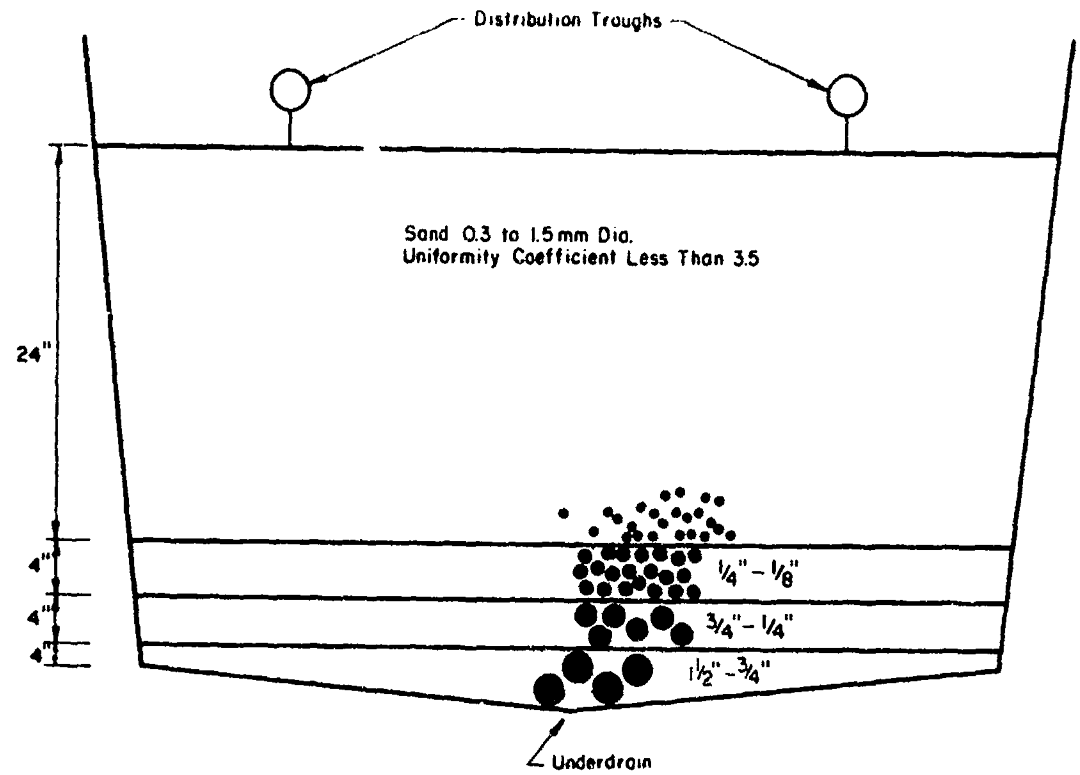


Figure 5. Sand filter. (From M. G. Teske).

Table 5

Effluent Quality with Recirculating Sand Filter System (From M. G. Teske).

	Approximate Range		
	High Average	Low Average	Overall Average
$BOD_{5,20}$	54.4 mg/L	2.5 mg/L	15.8 mg/L
Suspended solids	20.7 mg/L	0.0 mg/L	10.0 mg/L
Ammonia-nitrogen	19.9 mg/L	0.6 mg/L	8.46 mg/L

golf courses, and restaurants, private residences, and trailer parks. According to the Illinois Department of Public Health, the BOD and SS levels shown in Table 5 can be met consistently with proper operation. The systems in Illinois handle sanitary wastes and greywater combined (with some factory wastes in one instance); the treatment of greywater alone at remote Army sites should be equally successful. The size of the system might be reduced somewhat because of the weaker strength of greywater, but design criteria have not been established.

A regional engineer for the Illinois Department of Public Health estimates that a system would cost \$3500 to \$5000 for a single home (a family of four to five people); daily average flow of approximately 500 gal (1893 L). The cost is equivalent to that of a leaching field for a septic tank. Even assuming

that larger sand filtration systems would cost more than the home units, the Illinois engineer believes that the septic tank-recirculation sand filter system is the most economical treatment alternative for surface discharge of effluent.

The experience in Illinois indicates that no sand replacement is required after 4 to 5 years of continuous use. In the winter, the recirculation rate should be reduced to help prevent freezing. The ammonia-nitrogen concentration may be higher in the winter, but regulating agencies usually permit this. When the recirculation rate is reduced to zero, some odor may develop; however, the odor is not strong and can be quickly eliminated with an increase in the recirculation rate.

The rotating biological contactor (RBC) is another simple alternative that could be considered for greywater treatment.[2] The system can provide secondary treatment and partial nitrification. The rate of flow at remote sites on Army installations could be very small. For example, a rifle firing range of 180 people could produce a greywater flow of 1000 gpd (3785 Lpd), assuming water usage of 5 gal per person per day (18.9 L/cap/day). Some RBC manufacturers provide very small units for such use. CMS Equipment Ltd. of Ontario, Canada, for example, supplies ROTORDISK package treatment units (primary clarifier--rotating biological contactor--final clarifier) from 500 to 5400 gpd (1895 to 20,440 Lpd) capacities. All units are designed so that multiple modules can be installed to accommodate any treatment capacity.

The system costs in Table 6 are based on those provided by CMS Equipment Ltd. in June 1982. To arrive at the figures in Table 6, CERL added the cost of a cover to the price of larger units not supplied with one, and added a 20 percent installation cost to steel units, or a 30 percent installation cost to the internal assembly units (concrete tankage to be built by owner). The costs are quite competitive with the septic tank-leaching field system. However, operation and maintenance costs for an RBC system will be higher than those for the septic tank-recirculation sand filter system; in addition, the RBC system does not handle shock loads as well.

[2]For detailed information, see E. D. Smith et al., Evaluation of Rotating Biological Contactor Technology for Civil Works Recreation Areas, Technical Report N-126/ADA116759 (U.S. Army Construction Engineering Research Laboratory [CERL], 1982).

Table 6

RBC Costs
(Information for this table was obtained through personal communication with CMS Equipment, Ltd.)

Unit Capacity (gpd)	Model	Free on Board Price, Excluding Duty and Transportation Cost	
		Steel	Concrete*
Up to 500	S-12	$3600	N/A
2162 to 4324	S-30	$25,000	$21,000
2882 to 5764	S-40	$30,504	$24,500
5450 to 11,900	M-75	$46,320	$[illegible]9,000

*N/A = not applicable. Concrete work: 8.0 cu yd, 9.5 cu yd, and 25 cu yd per unit, respectively, for models S-30, S-40, and M-75, assuming $150/cu yd cost for concrete work. 1 cu yd = 0.76 m^3.

3 SELECTION AND COST ESTIMATES OF COMPOSTING TOILETS FOR U.S. ARMY INSTALLATIONS

This section provides guidance on sizing and selecting the proper number of composting toilets for servicing Army remote sites. The basis for this guidance is a facility in use year-round located in a moderate climate (Missouri) and having a minimum of 50 sq ft (4.65 m^2) of solar glazing on the south side of the tank enclosure. Northern locations (or high-altitude locations) will require more glazing, or some form of auxiliary heat, such as electric unit heaters, to maintain unit capacity through the winter months. Southern locations can provide equivalent service with little or no solar glazing.

The criteria for selecting the proper number of composting toilets to service a particular facility are completely different from those associated with vault or chemical toilets. Since vault and chemical toilets serve only to hold the wastes until they are removed for treatment, the only concern is that enough toilets and urinals be provided to service the troops in the time allotted for breaks. However, composting toilets are actually on-site treatment systems, and therefore the rate at which they are loaded becomes the main design criterion. It is still important to provide sufficient toilets and urinals by satisfying the loading rate requirement; an adequate number of toilets and urinals will most likely be provided.

Experience to date using composting toilets on Army training ranges indicates a realistic loading rate of 150 uses per day for a large (107 cu ft [3 m^3]) tank. This translates into one tank for every 25 troops, if the troops are on the range 24 hours a day (16 hours of training and 8 hours of sleep). If training takes less than 16 hours per day, then each tank can service proportionately more troops. An example might be a firing range which gets used most weekdays for 8 hours by 150 troops. Since the range is occupied for one-half of the 16 training hours each day, each tank can service 50 troops. This is because full-time use is figured as 16 hours of use and 8 hours of sleep. This rate is based on the unit having a continuously operating fan and solar glazing over the tank to aid composting during cold winter months. In this case, three tanks (each with two toilets and two urinals) would be required to service the 150 troops.

If a training area were used only 1 or 2 days each week, it stands to reason that fewer tanks are needed since the composting process can catch up with the higher loading during periods of unuse. Although this is true, in situations like this the critical criterion now becomes servicing the troops in the time allotted for breaks. To prevent long lines at the latrine (with the subsequent time impact on training), it is necessary to provide at least one fixture (toilet or urinal) for every 15 troops. Local practice must be considered when using this figure. If troops use the latrine on an "as needed" basis, one fixture can service a greater number of troops. On the other hand, if all troops must use the latrine during a short (less than 30 minutes) break period, then more fixtures are needed. A general rule is to allow an average time of 2 minutes per use. Therefore, if 100 troops must use the latrine in 20 minutes, a minimum of 10 fixtures are needed. Due to the relatively high cost of composting toilets, it might be advisable in cases like this to extend break times slightly, thereby allowing fewer latrines to

provide the necessary service. (Surveys at various Training and Doctrine Command (TRADOC) installations reveal that it is common practice to allow the troops to use toilet facilities on an "as-needed" basis.)

The Army operates many stations which are manned by only a few (four or fewer) persons. These include guard stations, missile sites, and the like. For these operations, small self-contained composting toilets (such as the Humus 80 or Carousel CR-100) are probably more appropriate. The basic differences between these and the large tank-type units is that they require far less space for installation and incorporate the use of an electric heater to aid composting. This is necessary since the decomposing mass is not large enough to retain the heat generated by the microorganisms. Due to their size, these self-contained units can usually be installed within an existing building, thereby eliminating the need for a separate latrine superstructure.

Although CERL is not testing these types of units for Army use, the literature indicates that they do perform well if they are not overloaded and if they are properly operated and maintained. The Clivus Multrum unit may also be considered for these types of stations.

Estimated Cost for Large Composting Latrine (1983)

At this time, only one company (Clivus Multrum USA, Inc., of Cambridge, MA) produces composting toilets in a size large enough for Army use. The largest tank, two toilets, one urinal, and all installation hardware, including vent stack and fan, costs about $6500. These units are also available through GSA, with discounts between 9 and 13 percent depending on the number of units purchased. This system can service about 25 people based on full-time year-round use. If a facility is in use only part of each day, or part of the year, the system can service proportionately more people. An example would be a firing range, which is used 8 hours a day, 5 days a week. In this case, one tank would service 50 people.

Besides the cost of the equipment, there are costs for the building, foundation, electrical work, and installation labor. A prefabricated wood and metal 6- x 8-ft building sold with the Clivus Multrum package costs about $3800 and requires about 32 hours of semi-skilled labor to erect. A site-built building of this size and durability would probably be more expensive, but might be competitive, depending on local costs. A concrete foundation for this unit costs about $3000 for excavation, form work, concrete, and backfill. A pole-constructed foundation (used telephone poles and treated lumber) costs about $1000.

In total, a completed latrine unit having two stools and one urinal costs between $15,000 and $18,000, depending on the type of foundation and local costs. This includes installation of a 10-ft (3-m) leach line, 50 sq ft (4.6 m^2) of fiberglass solar glazing, electrical work for fan and lights, and all installation labor. If several units are constructed, or if multiple tank latrines were built, the unit cost could be reduced to between $12,000 or $15,000 (not counting the additional 9 to 13 percent reduction through GSA purchase). These costs, together with the improved aesthetics, reduced maintenance costs (assuming some troop support), and reduced risks of adversely

affecting health and the environment, make composting a viable alternative to other remote site waste treatment systems.

Another benefit of composting is the extremely low amount of power it consumes. This feature makes it economically practical to operate the fan continuously using solar power. A solar package available from Clivus Multrum for $1200 consists of solar panels, storage battery, control unit, and DC fan. This system comes properly sized for the location and anticipated environmental conditions. In very remote areas, where the costs of providing power lines are prohibited and the distance to a wastewater treatment plant makes waste transport costly, composting might be the best waste management alternative.

	Pole Foundation	Concrete Vault Foundation
Excavation and backfill (for foundation and leach line)	$300	$840
Foundation (labor and materials)	$680	$1,950
Composting unit (tank, toilets, urinals, fan, hardware, and shipping)	$6,500	$6,500
Installation labor	$1,050	$980
Prefabricated building (includes shipping)	$4,700	$4,700
Labor to assemble building	$490	$490
Electrical work (labor and materials) (assumes power within 100 ft [30 m])	$420	$420
Solar glazing (labor and materials) (50 sq ft [3 m^2])	$490	$490
TOTAL	$14,630	$16,370

These cost figures were determined from actual installations on Army bases. Costs could vary with local conditions and price fluctuations. Total cost per unit could be reduced by an estimated 20 percent if multiple units are installed at one time.

Annual power costs will be $24 (assuming $0.10/kWh).

Annual operations and maintenance costs will be $480 (assuming troop labor for addition of bulking agent).

See Table 7 for a complete cost comparison between composting toilets and other remote site options.

Estimated Cost for Small Composting Latrine (1983)

Composting unit	\$2200
Installation labor	\$220
Electrical work (labor and materials) (assumes power in building)	\$110
TOTAL	\$2530

Annual power costs will be \$ 72 (assuming \$0.10/kWh).

Annual operation and maintenance costs will be \$240 (assuming troop labor for addition of bulking agent).

Even if there is not sufficient room in existing buildings for a self-contained composting toilet, this option might still prove to be cost-effective. Superstructure requirements are minimal using this type of unit since no excavation or tank support is needed. The building can be constructed on a slab, on grade, or on skids for mobility. Although this appears to be an ideal option, it must be remembered that each unit can service only four troops on a fulltime basis.

Vault Toilets Versus Composting Toilets

There is no question that composting toilet facilities are much more expensive than vault toilets, which are used most often at Army remote sites. Consider a vault toilet designed for the following conditions:

1. Rifle firing range used by 200 troops for 8 hours a day

2. One structure (including vault) = \$11,000

3. Pump outs (\$150 x 12 times each year) = \$1800/yr
Maintenance = \$ 335/yr
\$2135/yr

4. Life-cycle cost
(20 years, inflation rate 5 percent)
= \$40.80/yr.

The life-cycle cost of the vault toilet facility, \$40.80, is much less than the composting toilet's \$66.30 (Table 7).

Although composting toilets cost much more than vault toilets, there is a great deal to gain by protecting the environment from contamination by human wastes and by providing for the comfort of users of sanitary facilities in remote areas. These factors cannot be measured in monetary terms, but are important when Army base commanders and Facility Engineers decide whether composting toilets should be used to replace vault and chemical toilets. Data collected at Army installations indicate that troops are hesitant to sit on

the wooden seats associated with vault and pit toilets because they are rumored to be infested by a skin parasite. Consequently, the toilets are not used, which has the potential to lead to health problems in areas close to the building.

Of course, extending a sewage collection system to a remote site can also be very expensive. For example, one installation has a plan to supply all remote sites with water and electrical lines, sewers, and new toilet facilities. The projected cost for this is $6.4 million (1985 dollars), not including expenses for water, electricity, and sewage treatment.

Tables 7 and 8 compare composting toilets and other systems that can be used at remote sites on Army installations. Although the composting toilet system is more expensive than other alternatives, it compares well in other areas.

Army-Built Composting Toilet System

The costs of composting toilets can be reduced significantly if the Army designs and builds its own system. Appendix A describes the Farallones Institute's owner-built system. This system is small, and the Army could use it only at a facility such as a remote guard station; however, the basic design could be adapted to meet the Army's needs. A composting toilet suitable for Army application should hold a large mass of waste material, making it easier to maintain a pile temperature high enough for successful composting. The pile would need air ducts through it to provide an adequate oxygen supply. A sloping floor of approximately 30 degrees would allow the waste material to move slowly along by gravity. With these two major modifications, the only other change to the Farallones design would be to enlarge it. Designs of single and multiple units with common walls are being prepared by CERL to lower construction costs. Treated wood and concrete slab construction is being evaluated. Precast concrete construction of the major unit components might also be used to reduce construction and installation costs.

Another alternative is to combine the Farallones Institute and the Clivus Multrum design concepts (Figure 6). The unit construction cost for such a design should be about $1700. Other materials required to complete the toilet facility--e.g., toilet seats, urinals, air exhaust pipe, and exhaust fan (but excluding the superstructure)--cost approximately $500. The total cost would be about one-third the market price for a composting toilet of equivalent size. There should be no patent right violations, since the Army will be constructing these for its own use and will not be selling them.

Table 7

Cost Comparison for Composting Toilets and Other Remote Site Options

	Pit Latrine	Vault Latrine	Chemical Latrine (Port-a-Pot)	Vault Latrine Aeration	Composting Latrine
Initial Cost	$8,000	$11,000	-----	$2,000 (Retrofit) $13,000 (with new vault latrine included)	$13,500 (Without solar power option)
Annual Operation and Maintenance Costs	$640 (Relocation labor)	$1,800 (Pumping once a month)	$1,320 (Rental fee)	$890 (Includes pumping vault four times a year)	$490
Annual Energy Costs (@ 10¢/kWh)	-----	-----	-----	$480	$24 ($0 with $1,200 solar power option)
Per Capita Life-Cycle Cost	$137.17	$270.79	$1,62[illegible]	$168.54 (Retrofit) $298.54 (Including vault latrine)	$723.66 $734.09 (with solar option)
Capacity (Persons Serviced on Fulltime Basis)	100	100	10	100	25
Advantages	Low maintenance costs. Simple system.	Simple system.	Portable. No upkeep (when rented).	Uses existing facilities. Easy retrofit. Improves aesthetics. Less shock to treatment plant.	No treatment plant required. Low energy requirements. Adaptable to extremely remote uses.
Disadvantages	Environmentally hazardous. Aesthetically unpleasing. Presents health risks.	High operations and maintenance costs. Aesthetically unpleasing. Presents health risks. Hard on treatment plants.	Hard on treatment plant. Vandal prone. Low capacity.	Relative high maintenance costs. Still requires further treatment.	High first cost. Some precautions required (no lit cigarettes, no trash). Maintenance critical.

1. Present worth value on a troop capacity basis (includes all operation and maintenance labor and material, and first and replacement parts costs). Assumes: $20/hr contracted labor cost, $8.50 troop labor cost, $0.10/kWh energy cost, 10 percent discount rate, 20-year life except 5-year life on motor/blower unit used for vault aeration.
2. These costs were tabulated based on the best available information from a limited number of installations and do not necessarily represent conditions on all Army installations.

Table 8

System Comparison

	Water Requirement	Energy Requirement	Protection of Environment	Health Risk	Aesthetics	First Cost	Maintenance Cost and Trained Manpower Requirement
Composting toilets	None	None to minimal	Yes	Low	Acceptable	High to medium (Army built)	Low
Vault toilets, latrine, etc.	None	None	No	High	Unacceptable	Low	Medium (pump-outs)
Septic tank and leaching field	Yes	None to minimal	Yes	Low	Acceptable	Low	Low
Lagoon	Yes	None to minimal	Yes	Low	Acceptable	Medium	Medium
Package treatment plants							
RBC	Yes	Medium	Yes	Very low	Acceptable	High	Medium
Aeration	Yes	High	Yes	Very low	Acceptable	High	High
Connect to central sewerage system	Yes	High	Yes	Very low	Acceptable	Very high	Very high

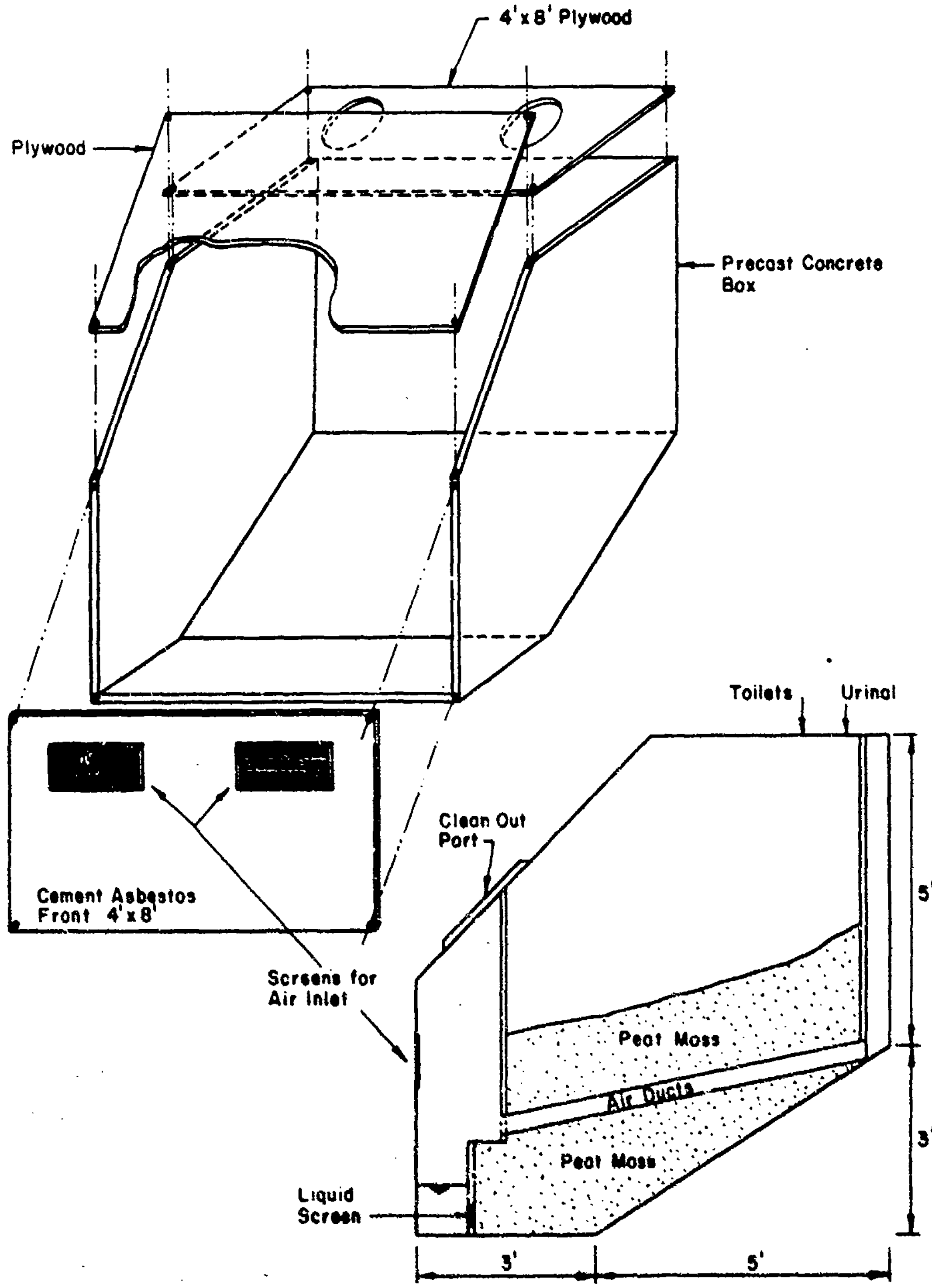


Figure 6. Design concept for Army-built composting toilet (1 ft = 0.3 m).

4 AERATED VAULT LATRINES

The Army currently owns hundreds of vault latrines, most of which are located on remote training ranges. These consist of a simple wood frame building containing about six toilets and four urinals located over an open concrete tank or vault. The vault, usually around 1500 gal (5700 L) in volume, holds the wastes only until they can be pumped and taken to a treatment plant for proper disposal.

The problems generally associated with vault latrines are unpleasant odors, unsanitary conditions, vector problems (flies), and high costs for pumping. Most of these problems result from the fact that the wastes are allowed to go anaerobic (i.e., they are not kept in contact with air). Oxygen-starved (anaerobic), wastes will support the growth of bacteria which produce end products of methane, hydrogen sulfide, and mercaptans. Coliform and other disease-related bacteria thrive in an anaerobic environment, and flies and other vectors can feed and reproduce on the stagnant surface. Although anaerobic decay does reduce waste volume, it is a relatively slow process.

By maintaining the wastes in a vault in a mixed aerated environment, most of the problems associated with vault toilets can theoretically be eliminated. Aerobic bacteria will be favored; these produce end products of carbon dioxide and water vapor, thus improving odors. Most disease organisms will be oxidized, thereby reducing the health risks. Flies and other insects cannot breed on a turbulent surface, so vectors are greatly reduced. Finally, aerobic decomposition proceeds at about four times the rate of anaerobic decay, which results in lower pumping requirements.

Bubble Aeration

The Army Corps of Engineers, Fort Worth District, has been experimenting with aerated vault toilets since 1974 at Ben Brook Reservoir recreation area. They have worked with various types of air compressors and blowers, and tried a number of diffuser types before developing the system they now use. This system consists of a lubrication-free, carbon-vaned blower which is belt-driven by a permanently lubricated motor. The blower's inlet is fitted with a replaceable-element air filter, and the outlet connects to a perforated air distribution pipe which is mounted along the vault floor. Air continuously supplied by this system acts both to mix the wastes and to supply oxygen to them. The Corps has used this system successfully on a number of their vault toilets since 1976. CERL has visited these systems in operation and has subsequently adapted them for use on Army latrines (see Figure 7). The following design calculations were used to arrive at the proper size unit for a given application:

Given:

75 troops training fulltime (16 hr training and 8 hr sleep each 24-hr period)
(120 g feces and 1.1 L urine)/troop/24-hr day
BOD_5: 10 g for 100 g feces, and 10 g for 1 L urine
1 kg O_2/kWh of blower output

$6 \text{ g } O_2/m^3$ air per meter of diffuser depth (transfer efficiency)
$2 \text{ kg } O_2/\text{kg } BOD_5$ required

Daily Loading:

75 troops x (120 g feces and 1.1 L urine per troop per day) x
(10 g BOD_5 per 100 g feces and 10 g BOD_5 per L urine)

= 1,725 g BOD_5

= 1.73 kg BOD_5.

Assume average vault depth of 1 m.

$[(1{,}725 \text{ g } BOD_5/24 \text{ hr})/(6 \text{ g } O_2/m^3 \text{ air})] \times (2 \text{ g } O_2/\text{g } BOD_5)$
$= 575 \text{ m}^3 \text{ air}/24 \text{ hr}$
$= 0.4 \text{ m}^3 \text{ air/min}$
= 14.1 cfm.

Power Requirement:

$1.73 \text{ kg } BOD_5 \times 2 \text{ kg } O_2/\text{kg } BOD_5 = 3.5 \text{ kg } O_2/24 \text{ hr}$
$= 0.14 \text{ kg } O_2/\text{hr}$

Since 1 kg O_2 is produced for each kWh blower output,

0.14 kW are required.

$0.14/(0.5 \text{ eff}_{motor}) \times (0.8 \text{ eff}_{drive}) (0.7 \text{ eff}_{blower})$

= 0.5 kW electrical power required

0.5 kW x 1.34 Hp/kW
= 0.67 Hp

Use a 3/4 hp motor.

Two motor/blower units were built based on these calculations and installed on Army latrines (one at Fort Leonard Wood, MO, and the other at Fort Dix, NJ). Each latrine was retrofitted with an aeration pipe which was then connected to the motor/blower unit (see Figure 7). Once the systems were installed, water was pumped into the vaults to cover the air pipe by about 6 in. (150 cm) for start-up. Initial performance has been good; see the Field Tests chapter (pp 50-53) for details.

Mechanical Aeration

An alternative method for aerating vault toilet wastes is mechanical aeration. This involves the direct mixing of the wastes using a motor-driven impeller combined with injection of air below the surface. The principle of partial waste treatment and improved latrine conditions is the same as with bubble aeration; however, the process should theoretically be more energy-efficient (1.3 to 2.0 kg/kWh motor output, as opposed to 1.0 for bubble

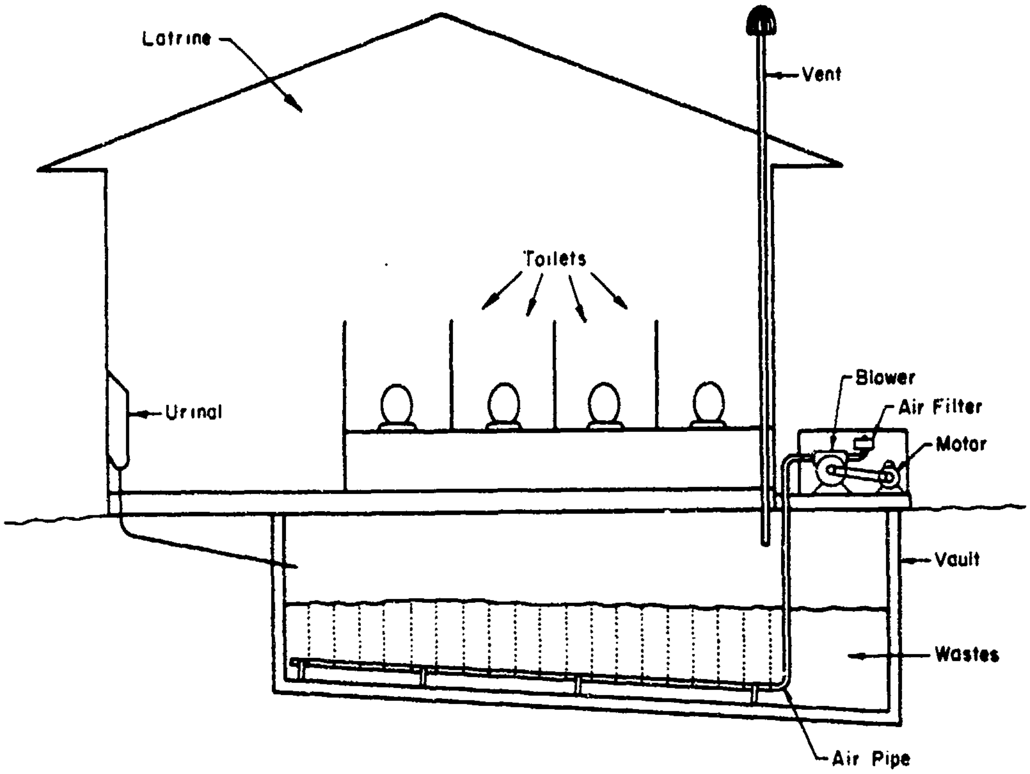


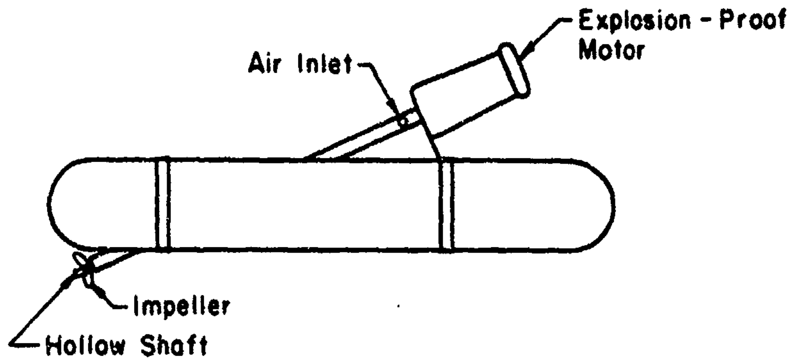
Figure 7. Aerated vault latrine (bubble aeration system).

aeration).[3] This is because mixing is done through direct contact as opposed to indirect air flotation.

The units being tested by CERL at Forts Leonard Wood and Dix are proprietary products of Aeration Industries of Chaska, MN. Each unit consists of a 1/2 hp motor which drives an impeller mounted on a hollow shaft. The entire unit is mounted on floats to maintain a constant immersion depth (see Figure 8). When operating, the vortex created by the impeller creates a low pressure at the end of the hollow shaft. This allows atmospheric pressure to force air down the shaft and into the waste, where it is vigorously mixed by the vortex. Initial testing of the units has identified certain design problems. The units have been modified and testing is continuing; see the Field Tests chapter (pp 50-53) for details.

With both bubble and mechanical aeration, there is a requirement for electric power. Unlike composting, these systems require too much energy on a continuous basis to make solar electric power practical. Also, since these systems are mechanical in nature, they will require periodic maintenance (see Table 8). However, if an installation already has vault latrines with power nearby, retrofitting them with aeration equipment could be a viable alternative for improved remote-site waste management.

[3] R. Laak, Wastewater Engineering Design for Unsewered Areas (Ann Arbor Science, 1980), p 45.



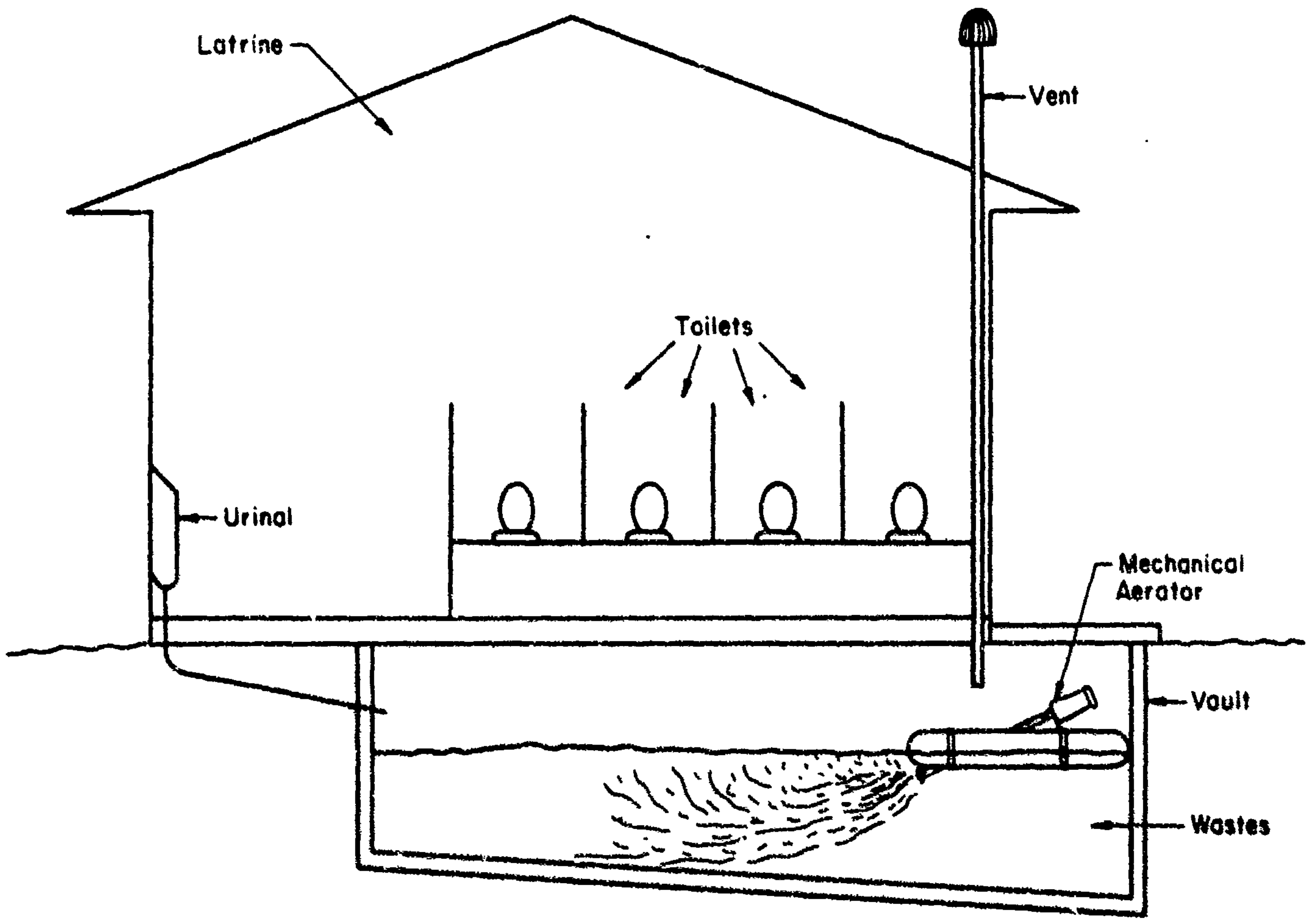


Figure 8. Mechanical aerator (above) and as installed in vault latrine (below).

5 FIELD TESTS

To properly evaluate composting and vault latrine aeration under actual Army remote site conditions, field testing was undertaken. Two composting latrines have been installed at each of three installations: Forts Leonard Wood, Dix, and Irwin. Additionally, two bubble aerators and two mechanical aerators have been installed in existing vault toilets at both Fort Leonard Wood and Fort Dix (Fort Irwin has no existing vault latrines). Both types of units are being field tested at Fort Jackson in 1984.

The information gained from these installations to date is primarily of an empirical nature (costs, ease of installation, and initial observations).

Composting Toilets

Relatively few problems were encountered in installing a composting toilet. The time required to install a system in a remote, self-contained structure is different from what is required to install one in a residence. Working under sometimes adverse weather conditions and at great distances from hardware supplies can add considerably to the installation time. Some problems were encountered with the prefabricated buildings manufactured by Gymmaster of Boulder, CO, which are supplied by Clivus Multrum. These were mostly associated with missing hardware and misaligned, predrilled holes in the first building assembled. However, these problems were resolved in the later buildings after discussions with the manufacturer.

What was learned through these installations is that assembly is only one small part of the work required. The excavation and foundation work, building assembly, electrical work, solar glazing installation, leach line installation, and finish work, such as gutters and landscaping, are all part of the total work required. The cost figures given in Chapter 3 were taken from actual installations and accurately represent realistic costs.

Initial performance of the composting toilets has been promising. Odors are minimal, and no fly populations have developed; as a result troop acceptance has been good. Only once after a change in command on one training range were there problems with troops not adding bulking agent; this problem was remedied after they were given the appropriate information about operating the system.

Some problems were encountered because the screen in the liquid baffle becomes plugged with peat moss and requires cleaning about every 8 weeks. Changing to a screen with wider openings would probably resolve this problem; however, it is not clear what effect this would have on the leach line life.

Initial operation of the composting latrines indicates that periodic (once a month) stirring of the pile is advisable. This procedure helps to mix the wastes with the bulking agent, making a more homogeneous mixture, which should improve composting. Since no end product has yet been removed from the installed units, the extent to which the system actually treats the waste is uncertain. It is significant, however, that the composting latrine has been in use for over a year and has gained user acceptability.

Despite the posting of warning signs in the latrines, cigarette butts have been observed in the compost pile more than once. Although no fires have resulted there is a potential hazard, since the bulking agent used is sometimes dry leaves or sawdust. Therefore, temperature-activated fire extinguishers have been installed in the compost tanks. This precaution is recommended because of the potential risks.

Bubble Aeration System

Retrofitting a vault latrine with a bubble aeration system is not a new idea. The Corps of Engineers has used this concept successfully at Ben Brook Reservoir, Fort Worth, TX, since 1976. This modification simply involves installing a motor/blower unit and connecting it to a perforated pipe which is attached to the vault floor (see Figure 2). Air continuously supplied to the waste supports the growth of aerobic organisms, which break down the wastes into carbon dioxide and water. Aerobic decomposition is about four times faster than anaerobic decomposition, so pumping costs are reduced. Preventing anaerobic decay also greatly reduces the odor in the latrine (only a slight ammonia smell is detectable in latrines with a high urine content).

A 200-cu ft (5.7-m^3) vault requires around 15 cu ft/min (.0435 m^3/min) of air for proper waste treatment. The air can be supplied by a positive displacement blower, belt-driven by a 3/4-hp electric motor. A 3/4-in. (20-mm) diameter PVC or cast iron pipe drilled with one hundred 1/8-in. (3-mm) diameter holes spaced evenly along its length distributes the air. More sophisticated distributors have been tried, but the concentrated wastes tend to clog them.

This system requires no daily maintenance. The latrine is used just as it was before; no chemicals or additives are needed. The aeration system is a mechanical device; however, and as such requires some minimum service. Weekly checks are recommended to assure continued system operation. No lubrication is needed if a carbon vane blower is used. The only maintenance required is changing the vanes and bearings every other year (a 2-hour job). The drive belt should be adjusted every other month and changed twice a year. An air filter on the blower requires cleaning or changing twice a year (more often in dusty areas). A motor with permanently lubricated bearings should operate continuously for 5 years without maintenance. Each time the vault is emptied, clean water should be added to just cover the distribution pipe for system startup.

Total material costs for this system are about $600, and it requires about 50 hours of skilled labor to assemble and install. Based on $0.10/kWh energy costs, power will cost $480 per year. This system, when installed on a latrine having six stools and four urinals, should support the needs of 100 persons on a full-time annual basis if emptied four times a year.

Although this system does not treat the wastes completely (periodic pump-out is still required), it significantly reduces oxygen demand, which reduces the load on the treatment plant when the vaults are emptied. This, along with the improved aesthetics and reduced pumping requirements it provides, makes vault aeration a viable alternative for remote site waste management where existing latrines are in repairable condition and power is available.

The bubble aeration system was built around an M-D Pneumatics, Inc., dry air pump. This unit was chosen because of its carbon vanes and sealed bearings, which means that no lubrication is required. The manufacturer claims that the only required maintenance is replacement of the pump vanes every 2 years. A permanently lubricated motor and belt drive were also chosen to minimize maintenance requirements. An air filter was placed on the pump intake to reduce pump wear caused by abrasive particles. Although this is a maintenance item, it should reduce overall maintenance time requirements because the pump vane life will be increased. The pump outlet was attached to perforated PVC pipe which is mounted 6 in. (150 mm) off the floor of the vault along its length. The motor/pump unit was housed in a locked metal box for protection from the weather and from tampering.

This system was easy to build and install. The only drawback to installing it was that the vault had to be completely cleaned, since personnel had to enter it to anchor the air pipe.

Initial operation of these systems has been good. Odor in the latrines has been greatly reduced, although a faint ammonia smell is detectable (probably due to the high urine input and resultant volatilization of ammonia). A vault which used to be pumped once a month has not required pumping since the aeration system was installed 4 months ago. It is uncertain at this time whether this is due to treatment, evaporation, or both.

After 2 months of operation, dissolved oxygen and BOD_5 tests were conducted on the wastes. The dissolved oxygen levels were at saturation and the BOD_5 was 120 mg/L. Upon settling, the samples showed a good settleable floc with an almost clear supernatant.

In the future, monthly testing will be done for BOD_5, DO, pH, temperature, and volume. Records will also be kept of maintenance requirements.

Mechanical Aeration System

The mechanical aerator used in the field testing was a proprietary unit manufacturered by Aeration Industries of Chaska, MN. It is essentially a floating aerator consisting of an explosion-proof 1/2-hp motor which drives an impeller mounted on a hollow shaft. The action of the impeller causes air to be drawn down the shaft and entrained with the wastes.

This unit was only slightly more expensive than the bubble aeration system and was less expensive to install. It had the added advantage that the vault did not have to be completely cleaned. The unit was simply lowered into the vault through the cleanout opening and connected to power. The unit is also less susceptible to vandalism (since it is in the vault), uses less power, is quieter, and has lower maintenance requirements (no filter or belt to change).

Initial operation of the unit was good; however, problems developed after about 2 months of operation. The hollow shaft became clogged (apparently due to foam reaching the air inlet), the end bearing was wearing excessively (probably due to high solids concentration), and the impeller became clogged with a rag. Each of these problems has been addressed in a redesigned unit which will replace one of the existing ones. However, it is premature to

assess whether mechanical aeration is practical for vault latrine wastes. Once subjective testing is begun, the same tests will be conducted as on the bubble aeration systems.

Mobilization Use

In addition to the applications discussed above, composting or aerated vaults could be applied to waste management during force mobilization. If a rapidly constructable waste-handling system with low water requirements is needed, either composting or aerated vaults could be used. Aerated vaults would be a good short-term solution; however, composting latrines are favored for a longer-term (1 year or more) installations, because over time the lower energy costs associated with composting would offset the higher first costs.

Health Considerations

Before composting or vault aeration are fully accepted for Army-wide use, they must be approved by the Surgeon General. To accomplish this, the Army Environmental Hygiene Agency is conducting a health hazard assessment of potential risks to users and maintenance personnel. Based on the results of this study, the systems might be modified (such as forced ventilation in the aerated vaults to control any aerosols which might be released), or more detailed maintenance instructions might be written. The results of the assessment, which should be available by mid FY84, will be published in a CERL technical report. While it is not anticipated that either of these systems will create greater hazards than pit latrines and vault toilets, it is recommended that Army installations limit any construction to one or two test units until the health hazard assessment is completed.

The Role of Pit Latrines and Conventional Vault Toilets in Army Use

Currently the Army has hundreds of pit latrines and conventional vault toilets in operation at remote sites. Even if composting latrines or aerated vault toilets become accepted for Army use, pit latrines and conventional vault toilets will still be used where composting toilets and aerated vault toilets are not practical.

For this reason, and because conventional vault toilets and pit latrines are often improperly designed/constructed and maintained, this report includes Appendix D, Vault Toilets: Design and Maintenance Considerations.

More information can be obtained from a U.S. Forest Service publication, Updated Vault Toilet Concepts. It is available from:

U.S. Department of Agriculture
Forest Service
Recreation Department
P.O. Box 2417
Washington, DC 20013
Phone: (202) 447-3706.

6 CONCLUSIONS

Composting toilets and vault aeration units appear to be workable solutions to remote site waste management problems, and under some circumstances may offer substantial advantages over accepted and more traditional systems such as pit, vault, or chemical toilets. While the long-term acceptance, operability, and health safety of composting and vault aeration have not yet been demonstrated for military applications, they should always be considered along with the other systems in selecting waste treatment for remote sites or mobilization purposes. Of the two, composting is advisable when new construction is being considered or in areas where power is unavailable. Vault aeration would be more cost-effective, however, when acceptable vault latrines are already onsite and power is available.

Initial field test results indicate that composting toilets:

1. Are relatively easy to construct.

2. Can receive require daily maintenance from troops.

3. Produce little odor when properly maintained.

4. Have high troop acceptability.

5. Are less expensive than chemical toilets but more expensive than pit latrines and vault toilets.

6. Are applicable for widespread use by the Army.

Bubble aeration systems for retrofitting existing vault toilets:

1. Are inexpensive and easily built.

2. Have relatively low maintenance requirements.

3. Improve aesthetics in vault toilets.

4. Reduce pumping requirements.

5. Have good troop acceptability.

6. Are applicable for widespread use by the Army.

This report provides interim selection/engineering guidance, economics, and O/M information based on literature reviews, private sector experience and limited field testing at Army installations. Consequently, this report serves as a state of knowledge definition of composting toilets and aerated vault technology. Upon completion of field tests and health hazard evaluations, final guidance will be developed.

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APPENDIX A:

RESULTS OF LITERATURE REVIEW AND FIELD SURVEYS

The literature on sewerless toilet systems--e.g., incinerating, oil-flush, and composting toilets--was reviewed to see if these systems could be used at remote sites on Army installations.* (Most of the studies deal with composting toilets; the Clivus Multrum seems to be examined most often in the literature.) Periodicals, books, and State and Federal reports on alternative waste disposal systems were examined. Thirty manufacturers of sewerless toilet systems were contacted for information. Responses were received from 17 companies. In addition, a telephone survey was conducted of facilities using Clivus Multrum systems on a relatively large scale.** Information on owner-built alternative wastewater disposal systems--as well as commercially marketed systems--was examined.

Large Composting Toilets

Some composting toilets have a large composting chamber below the area housing the toilet. This size ensures long composting times, resulting in a completely stable humus suitable for direct application as a soil conditioning agent, according to the manufacturers.

Two general designs for large toilets are now used in the United States: sloping floor type, or continuous; and box type, or vault. Two commercially available systems are being used in the United States. The Clivus Multrum has a sloping floor. The Soltran has a carousel composting tank supplemented by solar heat. Many owner-built systems in the United States are vault units.

A third manufacturer of public restroom facilities, Restroom Facilities Corporation, Reno, NV, will offer a large composting toilet system starting in May 1984. This manufacturer has produced high quality public restroom buildings for several years, but no evaluation of their composting system can be made until it has been tested under actual conditions.

Clivus Multrum

According to the manufacturer, more than 5000 units are used throughout the world, including every state in the United States. Except for 30 or 40, they are small, household units. Clivus Multrum has been used for more than 30 years in Scandinavia. Figure A1 shows a typical Clivus Multrum system.

The Clivus Multrum is available in several sizes. The largest unit, a tank with two midsections, is designed to handle 20,000 to 40,000 uses per year, depending on average annual temperature. A maximum of 150 uses per day

*Appendix B lists manufacturers of sewerless wastewater systems.

**A list of these facilities was provided by Clivus Multrum, Inc., Cambridge, MA.

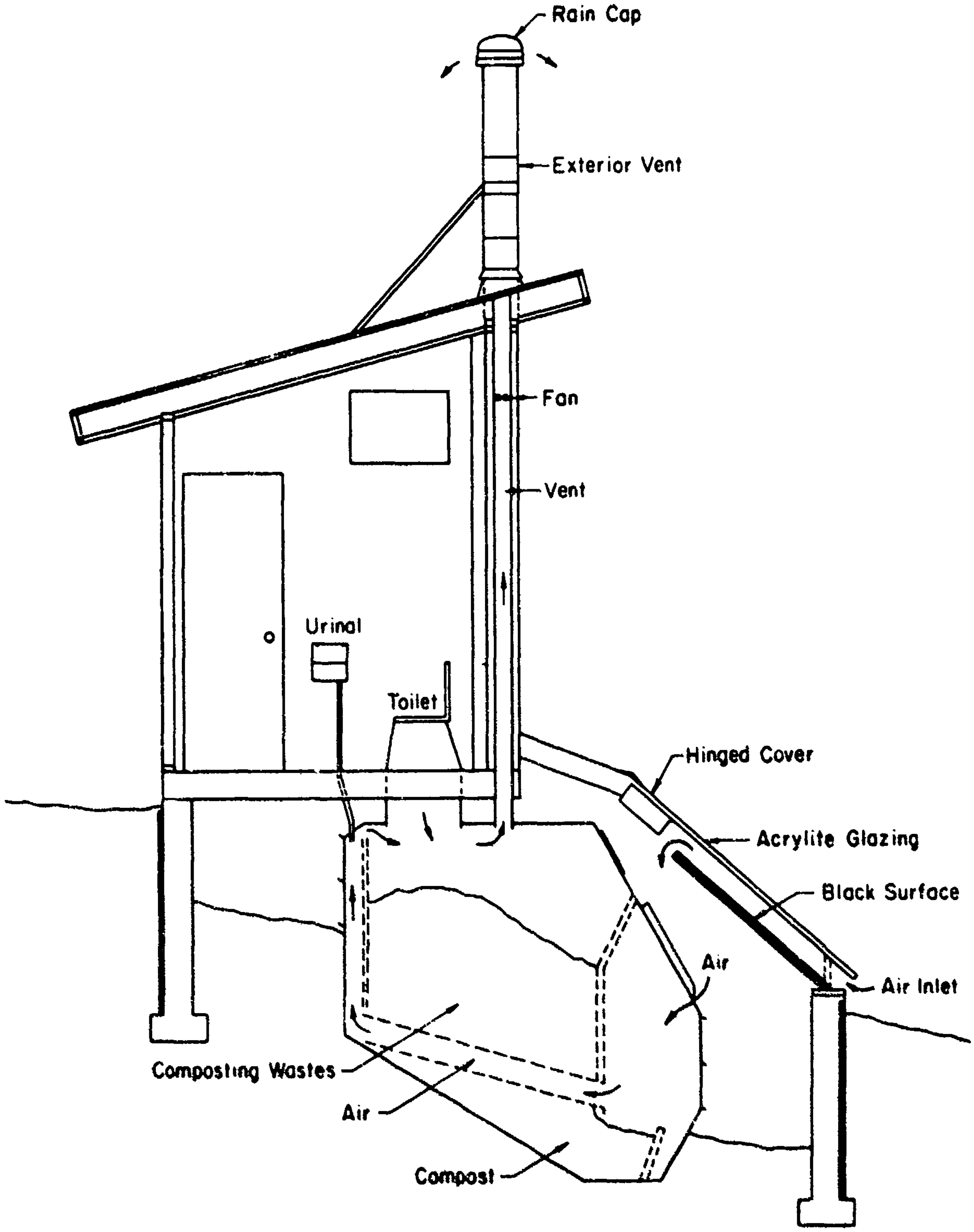

Figure A1. Clivus Multrum system showing a tank with two midsections installed in a typical public facility. (Suggested building design incorporates solar heated air intake.) (From Planning, Installation, and Operation Manual for Public Facilities, [Clivus Multrum, USA, Inc., 1981].)

can be sustained for long periods, and can be greatly exceeded for several days as long as the yearly limits are followed.[4]

In climates where the average temperature drops below an annual average of 55°F (18°C), usage must be reduced unless the composting chamber is heated. The manufacturer suggests a passive solar heating system to increase capacity in colder climates.

To be successful, a composting toilet requires adequate ventilation to maintain aerobic conditions, adequate temperature (at least 55°F [18°C]),[5] and the proper carbon/nitrogen (C/N) ratio. According to Fay and Leonard, "Microorganisms are controlled primarily by the C/N ratio, which should be 20:1-30:1."[6] Rybczynski states that "human excreta does not initially have the favorable carbon/nitrogen ratio of 15:1 required for good composting, and contains large amounts of nitrogen. Therefore, one of two things must be done: either large amounts of carbon must be added, usually in the form of cellulose materials (grass, leaves, foodscraps), or the nitrogen is reduced, usually by reducing the urine input."[7] Clivus Multrum recommends adding a bulking agent (e.g., peat moss, shredded bark, food scraps, dry lawn clippings). This gives the waste pile the proper texture and promotes liquid absorption, as well as acting as a carbon source.

Stoner notes that "the moisture content of the pile should be maintained between 40 and 70 percent; the pile should feel damp but not soggy. Moisture greater than 70 percent leads to anaerobic conditions; less than 40 percent and decomposition proceeds too slowly."[8] The manufacturer recommends inspecting the pile for adequate moisture content every 2 months; up to 5 gal (18.9 L) of water per day may be added for several days to moisten the pile thoroughly.

In a successful composting toilet, 90 to 95 percent of the waste matter decomposes to carbon dioxide and water vapor; the rest forms a stable humus. Compost must be removed after the unit has been in service for 2 to 5 years (depending on usage). Thereafter, this must be done annually. According to Clivus Multrum, the compost is stable and safe to handle.

In a study of Clivus Multrum compost, Fogel concludes that the material is beneficial as a soil conditioner, is stable, and contains lower amounts of potentially toxic metals than the "safest" sewage sludge.[9] Leich states, "Clivus Multrum compost compares favorably with chemical fertilizers."[10]

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[4] Planning, Installation, and Operation Manual for Public Facilities (Clivus Multrum, 1981), p 7.

[5] M. L. Kroschel, Experiences with Owner-Built, On-Site Waste Management Systems in California (Berkeley, CA: The Farallones Institute).

[6] S. C. Fay and R. Leonard, "Composting Privy Wastes at Recreation Sites," Compost Science/Land Utilization (January-February, 1979), pp 36-39.

[7] W. Rybczynski, "Appropriate Sanitation for the World's Poor," Compost Science (July-August 1977), pp 16-17.

[8] C. H. Stoner, Goodbye to the Flush Toilet (Rodale Press, 1977).

[9] M. Fogel, "Chemical Analysis of Clivus Multrum Compost" (1977).

[10] H. Leich, "New Options for a Sewerless Society," Compost Science (Summer 1976), pp 7-10.

However, the World Health Organization recommends that the compost be used only for ornamental plants and bushes.[11]

The Center for the Biology of Natural Systems analyzed the final product of the Clivus Multrum:

1. No E. coli were found.

2. The bacteria were similar in most instances to those in natural soils.

3. The predominant bacteria family was Bacillaceae, which is plentiful in soils.

4. The pathogenic bacteria found in the samples were species known to occur widely in soils.

5. The pathogen/total colonies ratio was 2 percent.

6. The ratio of aerobic/anaerobic organisms was similar to that of natural soils, indicating that the compost was moderately aerobic.

7. The age of the samples ranged from 3 to 23 years. There was no clear relationship between the number of colonies and the age of the compost.[12]

According to the manufacturer, some liquid end product can be expected to accumulate in the composting chamber. The amount of liquid produced varies with usage and climate. In a residential situation, the accumulation is about 300 gal (1136 L) per year.

When heavy daily use is expected, and urination is the predominant usage, much more than 300 gal (1136 L) of liquid will accumulate. The manufacturer states that "this liquid has been treated by the composting process and is safe and odor-free.[13] Table A1 shows bacterial analyses of the liquid end product.

Excess liquid must be removed so that it does not rise above the air inlet and cause anaerobic conditions. The manufacturer recommends the use of a drain plug or a submersible pump, but is vague about the ultimate disposal of the liquid. Subsurface disposal, depending on State and local regulations, is feasible, as is application to soils growing ornamental plants.

Operation and Maintenance. AMC[14] recommends the following, based on experience with several units:

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[11] M. L. Kroschel.
[12] H. W. Nichols, Analysis of Bacterial Populations in the Final Product of the Clivus Multrum (St. Louis: Washington University, Center for the Biology of Natural Systems, 1976).
[13] Planning, Installation and Operation Manual for Public Facilities.
[14] J. F. Ely, AMC Guide for Operating Compost Toilets (Gorham, NH: Appalachian Mountain Club).

Table A1

Bacterial Analyses of Liquid End Product
(From Clivus Multrum Health Considerations [Clivus Multrum, USA, Inc., March 1982]).

Site	Period of Use	Testing Laboratory	Fecal Coliform Bacteria per 100 ml
Domestic, NH	1 year	Process Research, Inc. c/o ERT Inc. Concord, MA	Less than 2
Domestic, MA	1 1/2 years	Process Reseach	50
	3 years	CBNS* Washington University St. Louis, MO	0 (also 13 types of soil bacteria)
Arc Project Prince Edward Island Canada	16 months	PEI Dept. of Environment Charlottetown, PEI Canada	0
Domestic #1 Ann Arbor, MI	7 months	Microbe One Stadium Blvd. Ann Arbor, MI	460,000
	9 months		1000
	1 year		0
Domestic #2 Ann Arbor, MI	15 months	Microbe One	430
	20 months	Microbe One	Less than 3
Wildlife Prairie Park Hanna City, IL 5 units	2 years	Peoria County Health Dept. U.S. Government Northern Regional Research Lab Peoria, IL	0

*Center for the Biology of Natural Systems, Washington University

1. The pile should be mixed every 6 to 8 weeks to maintain aerobic conditions.

2. Excess liquid should be drained.

3. Cellulose must be added regularly as a carbon source.

4. All inlet vents and pipes should be covered with fine mesh screening for insect control. The toilet seat should have a tight seal.

5. Finished compost should not be applied to food crops.

6. Periodic overloading should be avoided because it can cause an imbalance in the compost pile's populations of invertebrates, bacteria, and fungi.

Stoner says that problems with liquid buildup and odors in large units can be solved with a wind-driven rotary fan at the top of the stack or a small electric fan in the stack itself.[15]

Soltran

The Soltran system--manufactured by Ecos, Inc.--incorporates a solar-heated superstructure with either small composting toilets for home use or large composting tanks for public facilities. The large composting tanks (7 ft x 6 ft x 5 ft, or 8 ft x 6 ft x 5 ft) (2130 mm x 1820 m x 1520 m or 2440 m x 1820 m x 1520 mm) have sloping bottoms to separate excess liquid from the composting pile. Thus, the liquid can be:

1. Maintained at a specified level to provide thermal mass for heat storage, and to insure that the atmosphere beneath the composting pile is always saturated with water vapor.

2. Recycled directly to dry areas of the pile.

3. Evaporated completely by solar heating when input falls below evaporative capacity.

4. Removed easily if unpredicted usage exceeds the capacity of the system. A clear plastic flexible tube is used to indicate liquid level, and this can be connected to a pump if necessary.

The water vapor beneath the pile, and that from the solar-assisted evaporation of any excess liquid, is directed through the composting pile to prevent dehydration and to transfer latent and sensible heat. An "aerobic staircase" of steel and polypropylene allows air and water vapor to move through the pile. The "risers" of this staircase are empty, and spaced to promote rapid exchange of gases as the composting mass slowly slides by.

There was some concern about using large, fixed steel tanks as compost vessels. Therefore, in 1980, work was begun on a new design incorporating a fiberglass tank which could be removed for maintenance. In 1981, a

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[15]C. H. Stoner.

four-toilet Soltran of this design, using modified Carousel™ tanks, was installed in the Lawson Lake Park in Albany, NY (Figure A2). According to the manufacturer, this design incorporates various refinements in Soltran technology:

1. An efficient, passive solar collection system with a tough polycarbonate outer cover.

2. An integrated liquid and thermal storage and evaporation system.

3. A solar-heat-assisted passive ventilation system to improve air flow.

4. Saturated vapor recycling to improve composting by maintaining the proper moisture balance and transferring heat.

5. Air-tight, insulated construction and automatically controlled air flow to minimize heat loss and help maintain the best temperature for high-rate composting.

6. High-quality construction with attention to operating and maintenance details (e.g., smooth, easy-to-clean fiberglass interior).

The Albany, NY, Soltran was used daily by 160 day-campers and 20 staff members in July and August. During this time, each Carousel was rotated once (only two of the four chambers in each tank received excreta). When the facility was examined in October 1981, all liquids had completely evaporated; the solids' volume had decreased to 80 to 85 percent.

The smaller composting tanks are advantageous because, when filled, they can be removed easily and replaced with empty ones. Thus, fresh and composted waste are not mixed. The disadvantage of the system is that when it is used heavily, replacing the units can be time-consuming and expensive.

A Soltran public composting toilet facility allowing up to 300 uses per day sold for $11,500 plus installation costs in April 1982. In June 1982, Ecos, Inc., stopped production of the solar superstructure. Now, a set of building plans is sold with the composting toilet equipment. Customers have to purchase the material and build the solar superstructure on their own. The basic composting toilet equipment is $5000 to $6000 per unit, including installation. The owner-built solar superstructure costs about $2500.

Field Evaluations of Large Composting Toilets

A 2-year evaluation of composting toilets was done by the U.S. Department of Agriculture, Forest Service Equipment Development Center, San Dimas CA.[16] The performance of 30 installed systems at six sites was monitored (Table A2). The sites range from near sea level to 5000 ft (1542 m), and are exposed to various types of weather--e.g., rain, snow, dry heat, sun, and fog.

[16] M. E. Smith, Evaluation of Compost Toilets (San Dimas, CA: U.S. Department of Agriculture, Equipment Development Center, March 1981).

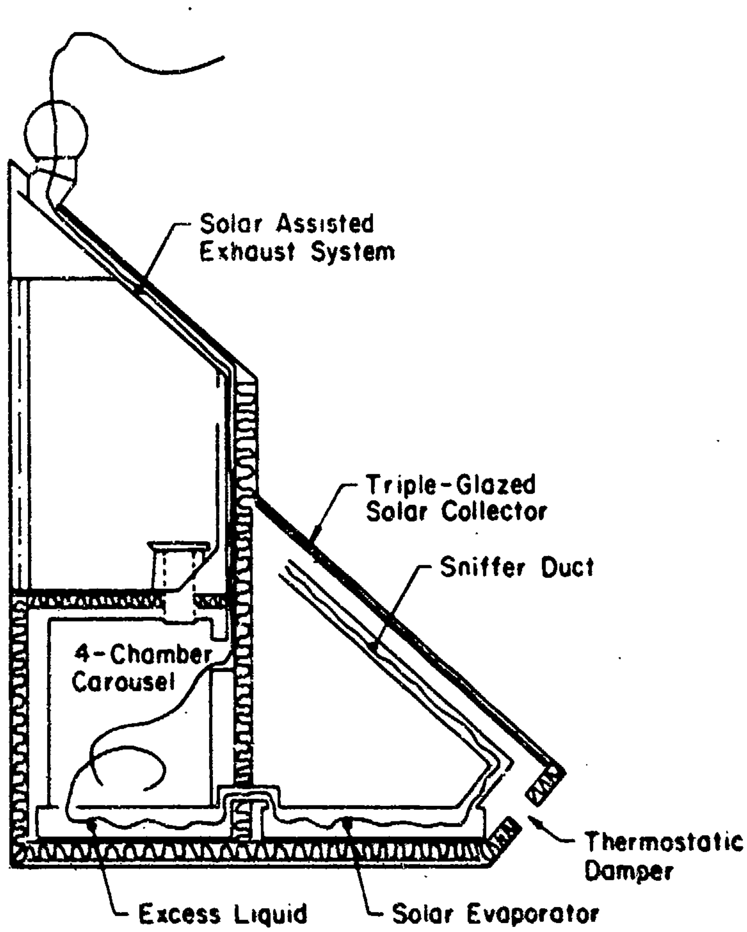

Figure A2. Soltran system. (From Operation and Maintenance Manual [SOLTRAN, January 14, 1982].)

Table A3 lists the ecological characteristics of these composting toilet systems. The bin composters rely on trained personnel to provide conditions for rapid decomposition of the waste into humus; the waste is moved to a bin and mixed with ground hardwood bark for a 2-week composting period. This operation is labor-intensive, requiring trained personnel and excellent records for proper management. The continuous composting is probably more applicable to Army installations.

The following observations were made during the survey:

1. All continuous compost sites were both anaerobic and aerobic digesting. Aerobic digestion, noted at the top and middle of the mounds, was indicated by the texture and warmth of the mound, and by an earthy aroma. Anaerobic digestion was also observed at the bottom of the mound and in the liquid accumulator of the composter. Anaerobic digestion was also indicated by sulfurous odors and uncomposted material.

Table A2

Field Evaluations
(From M. E. Smith, Evaluation of Compost Toilets.)

Site Number and Type of Composters	
Ottawa National Forest Sylvania Recreation Area, Michigan	19 bin composters
Cleveland National Forest El Cariso Ranger District, California	2 continuous composters
Angeles National Forest Mt. Baldy (private residence), California	1 continuous composter
Appalachian Mountain Club, Gorham, New Hampshire	6 bin composters 2 continuous composters
Farallones Institute, Occidental, California	1 bin composter 2 continuous composters
Wildlife Prairie Park Peoria, Illinois	5 continuous composters

2. All sites had blackwater* accumulation at or near the capacity of the system. Caretakers indicated that liquid was being removed from the composters every 2 to 3 months during the season.

3. Except for one bin composter, all had coliform counts above that recommended for end products. The National Sanitation Foundation Joint Committee on Wastewater Technology established that the end product should contain 200 fecal coliform per gram, or less, with a moisture content not exceeding 75 percent by weight. This indicates that the composting process had not eliminated the fecal and total coliform to a safe level, and therefore may not have eliminated dangerous pathogens.

4. The low ash content at all sites suggests that the waste was not fully digested. Therefore, the material should have continued composting or should have been dried and reused in another compost run.

5. Flying insects were observed at all sites, but there were not enough to be disturbing. At the Ottawa National Forest, the lids on all the composters' bins were not sealed; thus, it was not surprising that most mounds had maggots and breeding insects. Interviews with the caretakers indicated that the number of flying insects depended on the weather, the season, and the

*Blackwater is water carrying fecal matter and urine.

Table A3

Ecological Characteristics of Composting Toilet Systems
(From M. E. Smith, Evaluation of Compost Toilets)
[San Dimas, CA: Forest Service, U.S. Department of Agriculture,
Equipment Development Center, March 1981].)

Site	Sampling Date	Composter Type*	Total Coliforms/ml	Coliforms• MPN/100 ml	Fecal Coliforms MPN/100 ml	Total Solids (%)	Volatile Solids (%)	COD, mg/L	Ash (%)	Moisture Content % by Weight	Highest Temperature of Mound (°C)	pH
Appalachian Mountain Club												
Gentian Pond	7/20/79	(C)	$33(10)^2$	≥ 2400	≥ 2400	71.25	91.85	285,200	8.15	26.75	30.1	6.5
	8/21/80	(C)	$130(10)^2$	≥ 2400	1600	50.57	84.42	360,000	15.58	49.45	38.0	7.8
Speck Pond	7/26/79	(B)	$34(10)^2$	≥ 2400	≥ 2400	67.52	87.44	317,800	12.56	33.48	62.0	7.9
	7/25/79	(B)	$210(10)^1$	≥ 2400	≥ 2400	72.73	86.53	213,500	13.67	27.27	62.0	7.1
Gale Head	8/21/80	(B)	60**	46	46	33.26	81.16	212,000	18.84	66.74	12.8	8.0
	8/21/80	(B)	$31(10)^2$	≥ 2400	≥ 2400	25.25	60.06	67,000	39.94	74.72	53.5	7.3
Zeeland Hut (Site equipped with two bins)	7/24/79	(B)	$41(10)^2$	≥ 2400	≥ 2400	60.40	76.85	678,400	13.15	39.60	55.0	7.5
	7/24/79	(B)	$110(10)^2$	≥ 2400	≥ 2400	64.42	89.0	373,400	11.0	37.58	29.4	7.0
Mizpah Spring	7/24/79	(B)	$260(10)^1$	≥ 2400	≥ 2400	61.95	90.55	189,680	9.45	38.05	44.0	6.6
	7/24/79	(C)	$140(10)^2$	≥ 2400	≥ 2400	78.46	83.66	223,700	16.34	21.54	36.0	6.5
	8/21/80	(C)	$110(10)^3$	≥ 2400	≥ 2400	49.63	78.40	210,000	21.60	50.37	20.0	7.2
	8/21/80	(B)	$130(10)^2$	≥ 2400	≥ 2400	35.79	89.21	98,900	10.79	54.21	18.0	6.8
Liberty Springs	7/20/79	(B)	$164(10)^2$	≥ 2400	≥ 2400	61.10	86.66	198,800	13.34	38.90	72.2	8.3
	8/21/80	(B)	$43(10)^4$	≥ 2400	≥ 2400	59.78	43.50	185,000	56.10	40.22	55.0	8.0
Farallones Institute												
Visitors Center	4/27/79	(C)	$110(10)^3$	≥ 2400	≥ 2400	31.97	83.97	360,400	16.11	68.03	21.1	7.5
House	4/27/79	(C)	$59(10)^2$	≥ 2400	≥ 2400	24.83	85.27	516,000	14.73	75.17	21.1	7.5
Kitchen	4/27/79	(B)	$130(10)^3$	≥ 2400	≥ 2400	32.78	82.14	314,000	17.86	67.22	37.78	6.9

*(B)-Batch; (C)-Continuous.
**Sample taken from drying rack.
•2400 is the highest number obtainable using the lauryl-sulphate medium method; any numbers exceeding 2400 are recorded as 2400.

Table A3 (Cont'd)

Site	Sampling Date	Composter Type	Total Coliforms/ml	Coliforms+ MPN/100 ml	Fecal Coliforms MPN/100 ml	Total Solids (%)	Volatile Solids (%)	COD, mg/L	Ash (%)	Moisture Content % by Weight	Highest Temperature of Mound (°C)	pH
Cleveland National Forest												
Elsinore-Street Site	1/18/79	(C)	$71(10)^4$	$\geq$ 2400	$\geq$ 2400	17.37	76.88	1,280	23.12	82.63	20.0	7.5
	8/24/79	(C)	$280(10)^4$	$\geq$ 2400	$\geq$ 2400	21.28	69.10	84,520	30.90	78.72	20.0	7.1
	7/18/80	(C)	$35(10)^3$	$\geq$ 2400	$\geq$ 2400	28.70	87.76	15,620	12.24	71.30	20.0	6.4
Blue Jay	8/24/79	(C)	$19(10)^2$	$\geq$ 2400	$\geq$ 2400	10.90	68.30	207,460	31.70	89.10	21.1	7.1
	7/18/80	(C)	$160(10)^2$	$\geq$ 2400	$\geq$ 2400	17.4	51.30	12,300	48.70	82.60	21.1	7.1
Ottawa National Forest (Note: Of the 13 sites examined, only three were tested.)												
Clark Lake	8/2/79	(B)	$35(10)^4$	$\geq$ 2400	$\geq$ 2400	54.44	87.86	406,700	12.14	45.56	25.0	7.1
Pine Campground	8/16/80	[illegible]	$64(10)^3$	$\geq$ 2400	$\geq$ 2400	10.83	84.36	180,000	15.64	89.17	20.0	7.5
Balsam Campground	8/16/80	(B)	$110(10)^5$	$\geq$ 2400	$\geq$ 2400	9.33	83.60	230,000	16.40	90.67	16.7	8.4
Angeles National Forest												
Mt. Baldy	4/5/79	(C)	$64(10)^5$	$\geq$ 2400	$\geq$ 2400	27.78	88.34	242,500	11.86	72.22	21.1	7.6
	9/12/80	(C)	$44(10)^3$	$\geq$ 2400	$\geq$ 2400	44.62	73.51	261,400	26.49	55.38	21.1	6.9

condition of the mounds. Usually there were more insects during initial mixing and anaerobic digesting, when bin lids were not sealed or were left uncovered, and when continuous composter riser lids were left open.

Only the AMC had records on the management and administration of bin composters. The shortage of trained personnel and the lack of quality control were responsible for the poor performance of bin composting.

All managers of continuous composters indicated that they had little experience in administering such an operation. None seemed to be aware that aerobic and anaerobic digestion was occurring and that excess liquid was accumulating and causing an odor problem. Such conditions can cause water nutrient loading, transfer contagious diseases by animals, and threaten the health of operators.

The conclusions of the Forest Service survey are as follows:

1. This limited study showed that bin composting produced higher temperatures, allowing a greater reduction of organic material than with continuous composting.

2. Neither bin nor continuous composting reduced the fecal coliform to recommended limits.

3. Responsible administration is usually consistent with aerobic composting and the absence of (or poor) administration results in anaerobic composting.

4. Most ash contents were low and chemical oxygen demand (COD) was high, which indicates that more composting could be achieved.

Important parameters were not met with the two types of composters. However, if the composted waste can be buried shallowly at or near the site, and if this does not threaten public health, the manager has solved the waste disposal problem. The Forest Service survey recommends that continuous composters adhere strictly to the manufacturer's operation manual, with particular attention to liquid accumulation, compacting, channeling, drying, flying insects, mixing, and odors.

CERL interviews with Forest Service personnel during June 1982 confirmed many of the findings of this survey. In addition to emphasizing proper and diligent service and management of the composting toilets, Forest Service personnel maintain that composting toilets are good containment units, but do not successfully compost the waste material. Most units either are not insulated well enough or do not have enough mass to keep the pile temperature at 130° to 140°F (54° to 60°C). This range is required to kill off pathogens within a period of hours. The composted material can be spread very thinly on the ground so that the ultraviolet radiation from sunlight can kill the remaining pathogens; this takes about 3 hours. The land spreading must be done at a site with no public access; otherwise, local authorities must approve disposing of the "composted" material in sewage sludge and refuse landfill sites.

Recently, large continuous composting toilets in public facilities have been provided separate urinals so that much of the liquid can be diverted

around the mound to avoid flooding and anaerobic digestion conditions. At the bottom of the unit, the liquid is drained through a pipe, so there is no accumulation. With this arrangement and other maintenance, Forest Service personnel believe that large composting toilets can be used satisfactorily, and that the waste material might be composted to a more stabilized condition. However, without extensive field testing data, the characteristics of this "composted" material and of the drained liquid are still of concern to the Forest Service.

Another survey of the performance of composting toilets was conducted by the California Department of Health Services.[17] In this field evaluation program, 34 composting units used in private homes were studied for 11 months. The California Department of Health Services measured pH, temperature, moisture, and volatile fraction of both internal process (waste pile) and the end product. The microbial content of the end product was also determined. In addition, field observations--e.g., the presence or absence of odors and vectors--were included in the findings.

The following composting toilets were studied: Clivus Multrum, Toa-Throne, Vault, Drum, Mullbank, and Bio-Loo. The main finding of this study was that units did not compost successfully. This was indicated by one or more of the following symptoms: waste pile temperature was too low, moisture levels were too high (greater than 60 percent), pH was outside the desired range, volatility of the waste pile content was low, anaerobic decomposition generated hydrogen sulfide odors, insect vectors were in the toilet solids compartment, and all end products carried parasite forms, which are pathogen indicator organisms.

The following reasons were cited for the improper functioning:

1. In general, the users were either unwilling or unable to keep their systems aerobic. Circulation by mechanical fans or movements by gravity, or topping bar and rotor did not create and maintain aerobic conditions. Frequent manual mixing is probably the only way to maintain aerobic conditions but most systems were not designed to allow convenient access to the solids compartment

2. Inadequate aeration was caused by excess moisture in the waste pile.

3. The carbonaceous content was inadequate for composting to occur.

4. Fresh material may have short-circuited to the section of the toilet containing older waste material.

5. Vendors did not tell users about the importance of regular service and maintenance.

Although these observations apply only to composting toilet systems in homes, the findings at a few composting toilet facilities for public use are

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[17] K. M. Enferadi, <u>A Field Evaluation of the Waterless Toilet as an Alternative to the Failing Soil Absorption System</u> (Berkeley, CA: California Department of Health Services, 1981).

similar. Clearly, composting toilets must have proper care, service, and management if they are to function properly.

One European study discusses the use of composting toilets for year-round houses and vacation homes. The Project Committee for Purification of Sewage Water, Norway, examined not only composting toilets, but also outhouses, toilets with small or large collection containers, pressure and vacuum toilets, plunger toilets, chemical or oil recirculating toilets, portable water-closets, freezer toilets, parceling toilets, incinerating toilets, and Bio-bed recirculation toilets. In addition to providing data on performance, the report gives advice about the installation and operation of composting units.[18]

Eleven different composting toilet models and five prototypes were tested during 1976 and 1977 in Norway. Both vacation home use and permanent home use were simulated. Operation and performance monitoring included measurements of aeration, weight loss, dry matter, ash content, pH, C/N ratio, fecal coliform, salmonella Tel-aviv inoculation and recovery, and polio virus inoculation and recovery.

All composting toilets for vacation home use had pile temperatures higher than the room temperature after 2 weeks of operation. In toilets without heat elements, pile temperatures dropped back and remained slightly higher than room temperature after 7 to 12 weeks of operation. Some models experienced fluid accumulation and insufficient aeration, leading to little weight loss.

There was a significant reduction in fecal coliform (by about 10^6 times) in all composting toilets. Salmonella Tel-aviv reduction was 50 percent after 1 week, and was almost complete after 8 weeks. This took place even though the pile temperature in most of the composting toilets was never higher than 121°F (49.5°C). Polio virus did not survive after 4 weeks of operation. No fecal coliform was detected in the vent pipes of any of the toilet facilities tested.

Large composting units in permanent residences did not always maintain a steady temperature inside the toilets. Some could not maintain a temperature at or above the room temperature (64°F) (17.8°C), even when heat elements were provided. However, others could maintain a temperature much higher than ambient without heating elements if enough mass had accumulated in the unit. Insulated units could hold the temperature better than those without insulation. Only one unit (a small composting toilet with heating elements) had the temperature increase within a short time that could lead to heat sterilization.

Ash content generally increased in the composting toilets. An increase of 20 to 24 percent would mean that 25 percent of the organic matter disappeared during composting. The changes in ash content indicate that 20 to 45 percent of the dry matter disappeared during composting.

[18] Alternative Solutions to Toilets for Vacation Homes and Permanent Residences, translated for U.S. Environmental Protection Agency, TR 79-0351 (Project Committee for Purification of Sewage Water, Norway, November 1979).

Only the fecal coliform content was monitored in the composting toilets for permanent home use. Again, there was a significant reduction, equivalent to that for composting toilets in vacation homes.

Another European study was done by Stein Oberg, Norwegian Agricultural College, Microbiology Institute.[19] Eighty-three composting toilet facilities of eight different brands were tested from the fall of 1978 until May 1979; all were used in permanent homes. The units included large (five to six persons per day) and small toilets (two to three persons per day).

Some of the models delivered had equipment missing; some did not have the installation and usage instructions needed for proper operation in houses occupied year-round. Small composting toilets were relatively easy to install. They were the only recommended solution for placement on the second floor. Most worked satisfactorily, but generally required more maintenance and servicing (such as hand tool mixing of pile).

The large units had composting tanks completely or partially outside the toilet room and required professional installation to function satisfactorily in varying climatic conditions. Cold did cause significant problems in most of the large composting toilets; the temperatures of the units were too low, and excess liquid accumulation resulted from poor ventilation.

The best units were those that provided excess liquid drainage to a separate compartment for heat evaporation, and those equipped with a separate-chamber composting tank (Snurredass, or Carousel as they are called in the United States).

Selection Considerations

Based on CERL's literature search and field surveys, it is clear that several advantages and disadvantages of large composting toilets should be considered before these units are installed for actual use on Army installations.

Advantages of the Clivus Multrum.

1. No water is required.

2. Little energy is required.

3. Waterborne pollution is reduced.

4. A reduction in subsurface sewage disposal system requirements (by about 40 percent) may free for development land currently considered unsuitable.

[19] S. Oberg, Biological Toilets for Use in Year-Round Houses: Status Report 1, Current Experiences From Practical Studies, translated for U.S. Environmental Protection Agency, TR-81-0083 (Norwegian Agricultural College, Microbiology Institute).

5. The units are aesthetically pleasing.

6. The toilets are a sewerless, on-site waste treatment alternative.

Disadvantages of the Clivus Multrum.

1. According to Ove Molland, "In contrast to water closets, the waste material in a biological toilet is treated on the site; it is a 'miniaturized sewage plant'. This puts demands on the construction and use of the toilets."[20]

2. The initial cost is relatively high.

3. The unit takes up considerable space.

4. In general, State and local officials approve the use of these units only on a case-by-case basis because there is no effective control over operation and maintenance.

Small Composting Toilets

Mull-Toa

The Mull-Toa, also known as Bio-Let, Bio-Mat, and Soddy Potty, was formerly known as Humus-5 or Mullbank (Ecolet) (Figure A3). This unit features a thermostat-controlled air-recirculation system that evaporates the moisture and maintains aerobic conditions. The heating elements in the air-recirculation pipes keep the temperature inside the unit at about 95°F (35°C). A built-in hygrometer monitors humidity, and the air-outlet control can be adjusted to maintain proper humidity. There is a fan in the pressure chamber to ensure a continuous air flow; a diffuser installed on the upper part of the vent stack prevents unpleasant odors outside the toilet.

According to Stoner, "During the first one to three months or until the contents have reached up to the stirrer, the toilet cannot accommodate more than about four quarts (3.8 L) of urine in each 24-hour period. After this period here is enough bulk in the tank to absorb five to six quarts (4.7 to 5.7 L) each full day....The mold box need be emptied only once a year. The contents should be buried at least a foot (305 mm) below ground level around ornamentals."[21]

The cost of the Mull-Toa, as of April 1982, was $958 inclusive. It is designed for four people and will take only very occasional overloading. An updated version, known as the HUMUS-80, features an improved stirring mechanism and sold for $799.95 in March 1983.

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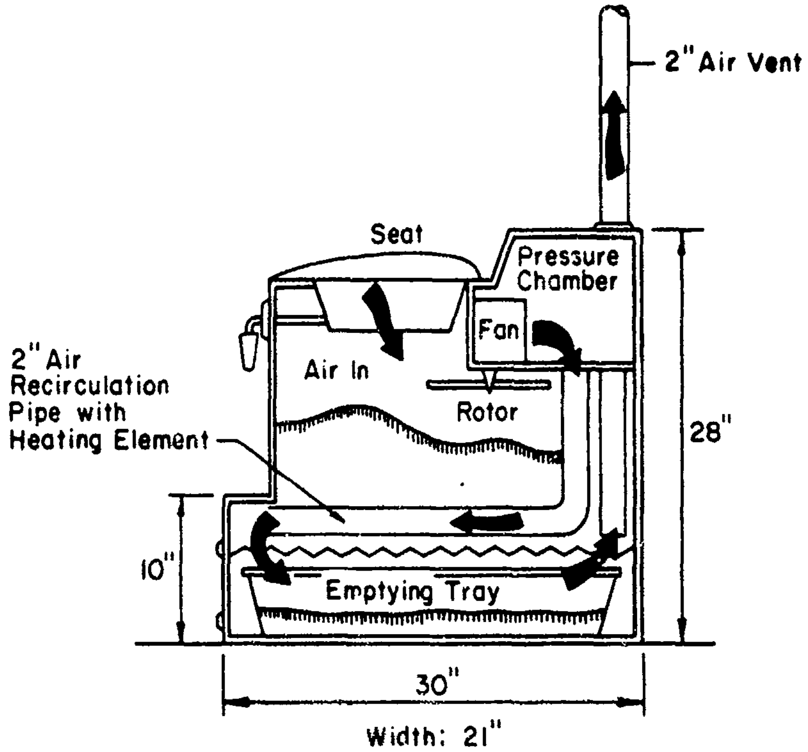
[20] Ove Molland, "Norway Introduces Quality Standards for Biological Toilets," in Alternative Wastewater Treatment, eds., A. S. Echum and R. W. Seabloom (D. Reidel Publishing Co., 1982), pp 245-254.

[21] C. H. Stoner.



Cross-Section of the Mull-Toa Toilet. The Fan in This Unit Pushes the Air Through and Out the Tank, Rather Than Pulling it Out, as in the Other Toilets.

Figure A3. The Mull-Toa. (Reprinted from C. H. Stoner, Goodbye to the Flush Toilet, c 1977 by Rodale Press, Inc. Permission granted by Rodale Press, Inc., Emmaus, PA 18049.)

Bio-Toilet 75 (and 75B)

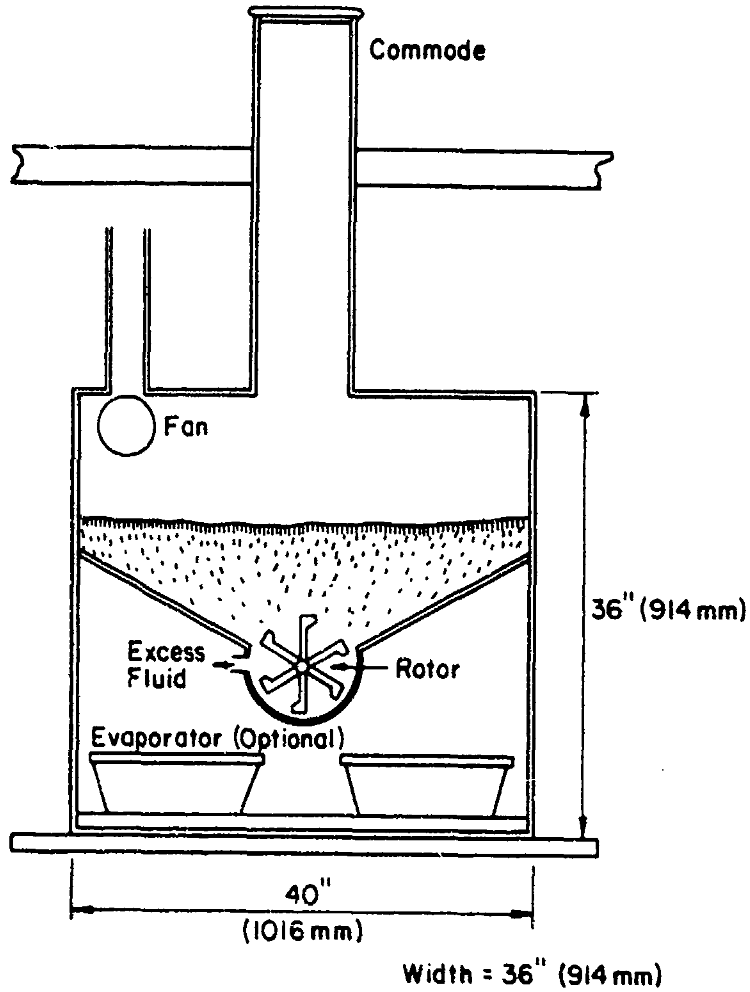
To improve evaporation, the Bio-Toilet (Figure A4) has three compartments instead of one. According to the manufacturer, this allows the unit to serve up to 10 people. However, this unit requires space under the bathroom floor for composting; thus, it is not technically a "small" unit. Electrically heated air is forced through the composting tank. A rototiller-type blade operates when the toilet seat is lifted, and automatically mixes the pile. An exhaust fan is located inside the chamber; there is a diffuser on the upper part of the vent stack.

Bio-Toilet A

The Bio-Toilet A is a rotating-drum-type unit that can serve six people on a regular basis (Figure A5). The drum rotates slightly each time the toilet seat is lifted for use; this mixes and aerates the pile. The drum is tapered, and the rotation plus gravity tend to convey composted product gradually to the tray, where the contents undergo further decomposition.

According to Stoner, "another purpose of ths rotating drum is to provide a barrier between the toilet opening and the decomposition tank. When the drum comes to a stop, the opening is on the underside of the drum so that upon lifting the lid, you see nothing but the topside of the drum."[22]

[22]C. H. Stoner.



The Rototillerlike Blade in the Bio Toilet 75 Automatically Mixes and Aerates the Pile After Each Use.

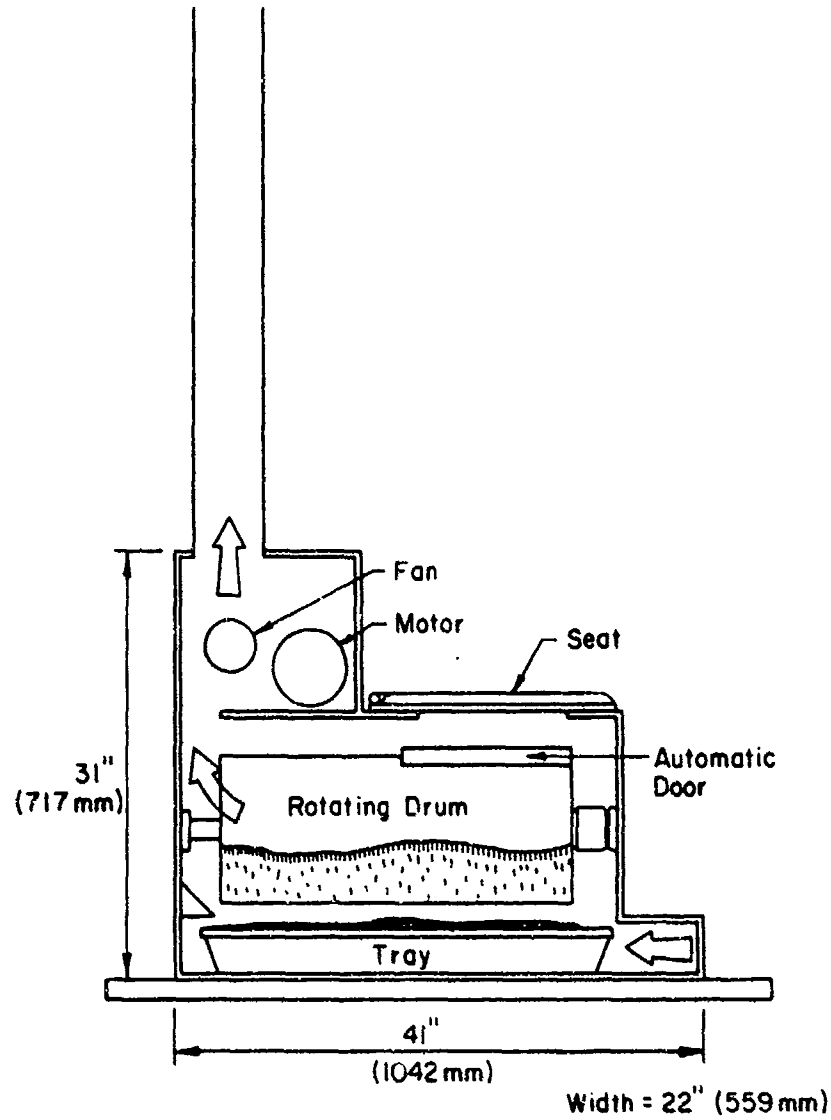
Figure A4. Cross-section of the Bio-Toilet 75. (Reprinted from C. H. Stoner, Goodbye to the Flush Toilet, c 1977 by Rodale Press, Inc. Permission granted by Rodale Press, Inc., Emmaus, PA 18049.)

No heating is required, but the manufacturer recommends that the unit be installed in a room where the temperature is no lower than 65°F (18.3°C) when the toilet is in use. The unit has an exhaust fan acting as a diffuser near the top of the vent stack.

Bio-Loo

The Bio-Loo is similar to the other small toilets, with one exception: the built-in heater can achieve temperatures high enough to pasteurize the organic matter (Figure A6).

Stoner describes the operation as follows:



The Bio Toilet A Has a Door On Top of the Rotating Drum That Opens Only When the Toilet Seat Lid is Pushed Back All the Way so that the Pile Beneath it is Hidden Most of the Time.

Figure A5. Cross-section of Bio-Toilet A. (Reprinted from C. H. Stoner, Goodbye to the Flush Toilet, Permission granted by Rodale Press, Inc.)

When the drawer is full (which will happen about every other month if four people are regularly using the Bio-Loo) the heater should be turned up to 158°F (70°C) and left on automatic time for six hours. The Bio-Loo people claim the wastes are then safe to use anywhere. If you don't wish to use the pasteurizer, you can remove the contents of the drawer and incorporate them in a healthy compost pile for at least six months.

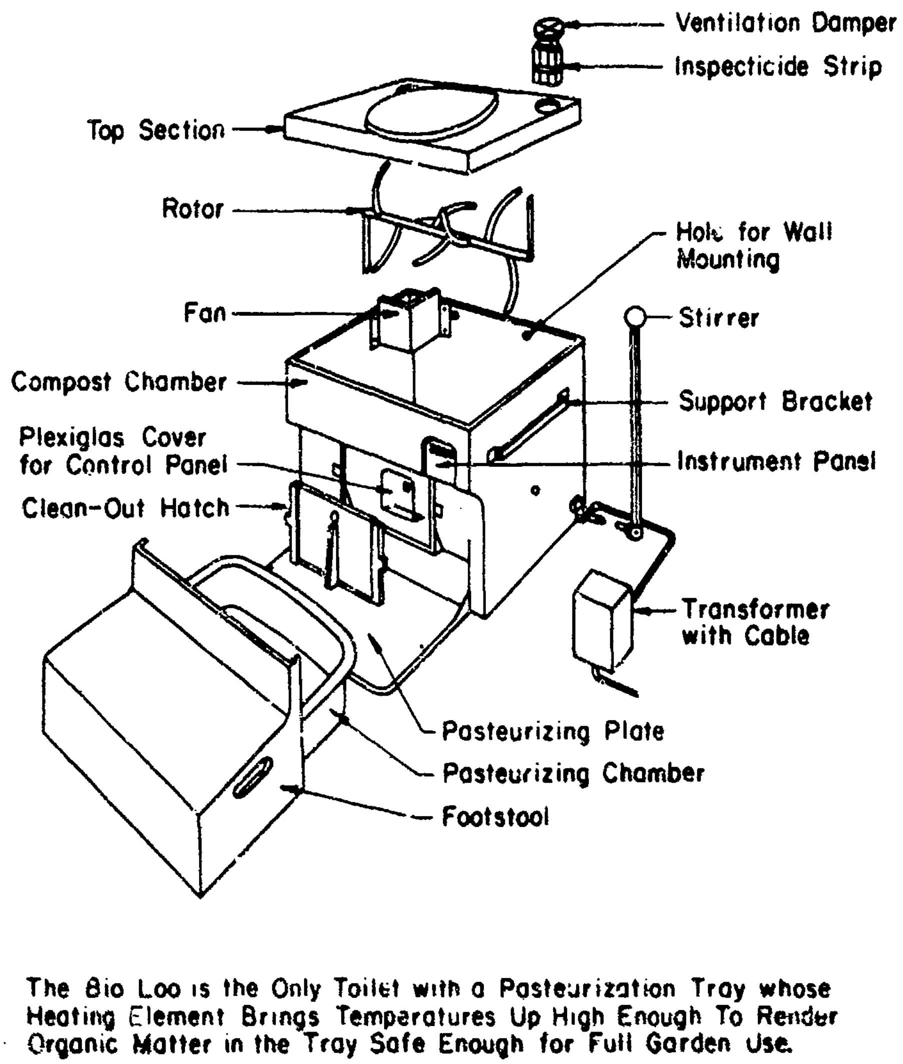


Figure A6. Bio-Loo toilet. (Reprinted from C. H. Stoner, Goodbye to the Flush Toilet, permission granted by Rodale Press, Inc., Emmaus, PA 18049.)

Such pasteurization or long composting is necessary in the Bio-Loo because kitchen and bathroom wastes don't remain in the unit long enough to decompose completely. The Bio-Loo has the shortest storage time of all the toilets we know -- only about 2 months.

A manually operated steel rotor is used to stir the pile after each use; a fan in the compost chamber provides ventilation.

Bio-Recycler

The Bio-Recycler is a small toilet with a separate cylindrical collection/composting chamber (Figure A7). After each use, a foot switch activates

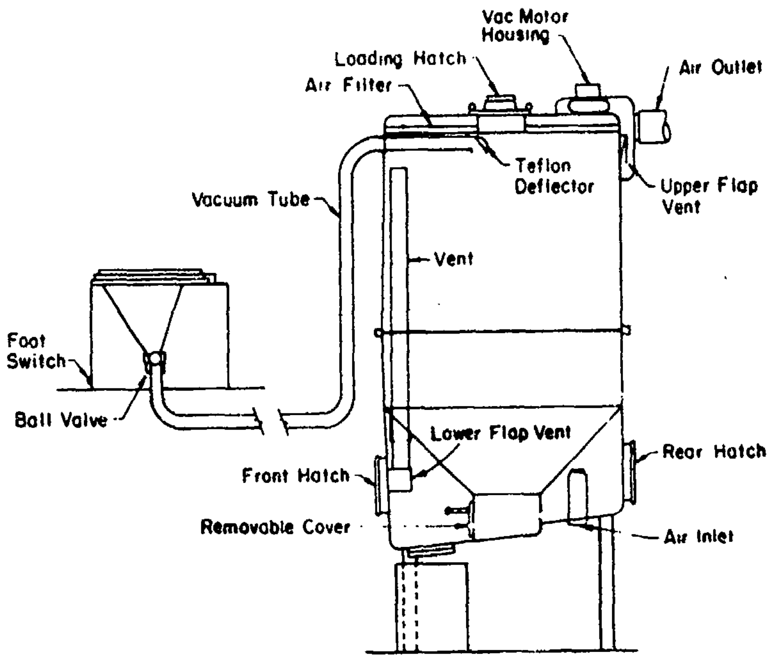


Figure A7. Cross-section of the Bio-Recycler. (From Bulletin [Bio-Recycler Co.].)

a vacuum motor, which conveys the waste from the toilet to the tank, where it hits a teflon deflector and settles into the tank.

According to the manufacturer, this high-velocity vacuum delivery and the subsequent scattering of the waste into small particles upon impact with the teflon deflector provide optimum initial aeration and dispersion.

A loading hatch at the top of the chamber allows the addition of kitchen scraps or shredded leaves. A porous membrane at the bottom of the chamber allows the drainage of the "compost tea" into a 5-gal (18.9 L) container.

According to the manufacturer, the sloping bottom of the lower chamber provides 6 months of compost aging in addition to upper chamber decomposition. Compost is removed in small amounts monthly or as needed.

The manufacturer recommends that the toilet hopper be sprayed with 1 or 2 oz (29.6 to 59.1 ml) of water after each use. No heating elements or coils are used, and ventilation is provided through flapper valves. Energy to operate the vacuum motor is required; the motor size is not specified.

The cost of the unit in March 1982 was $1800.

Biolet

The Biolet is a modular toilet with thermostatically controlled heating coils to maintain a composting temperature of about 95°F (35°C). For ventilation in the chamber, there is a fan with three speeds.

The manufacturer lists the following capacities: four adults, year-round use; five to eight persons at less than full-time use; and up to 15 persons for one 8-hour shift for industrial/commercial use.

According to the manufacturer, the unit "consumes no more power than two or three 60-W light bulbs, and much less if you live in a warm climate."

The cost in March 1982 was $1125, FOB, Beatrice, NB.

The Carousel Toilet

The carousel toilet has a circular composting chamber containing four compartments. As one compartment is filled, the chamber is rotated to the next compartment. The mass in the first chamber decomposes until it is time to rotate to it again, when it is emptied.

The manufacturer recommends a heater for year-round applications, and a fan for ventilation when electricity is available. In March 1983, the cost, excluding accessories and heating/ventilating equipment, was $1733 for a small unit and $2133 for a large unit. The manufacturer claims the small unit can serve two to four persons.

The Envirolet Toilet

This is a small, modular, heat-assisted composting toilet. One control is for the heating and ventilation system. Air flow is regulated by an air-vent control, which is operated automatically by a built-in hygrometer. The cost of one unit was $799 in 1982.

Owner-Built Systems

Many different systems using the principles of composting have been designed for individual use by homeowners. These systems vary greatly, depending on the needs and the expertise of the builder.

A typical design is the composting privy built by the Farallones Institute, Berkeley, CA. It is an alternating, vault toilet using the principles of thermophilic (high-temperature) composting (Figure A8). To accomplish thermophilic composting, aeration and mixing are required to achieve conditions suitable for rapid biological activity.

Kroschel describes the system:

> The Farallones Privy consists of a two-chamber concrete block vault, 4 x 8 feet (1.2 x 2.4 m) high (outside dimensions), set on a 4-inch (102-mm) concrete slab dished out to retain liquids. The interior is painted with an asphalt emulsion to retard the absorption of moisture. One face of the box has two removable plywood doors with screened air inlets, which allow access for inspection, mixing and removal of the compost. Immediately behind the doors, recessed several inches, are heavy wire mesh baffles, which promote aeration

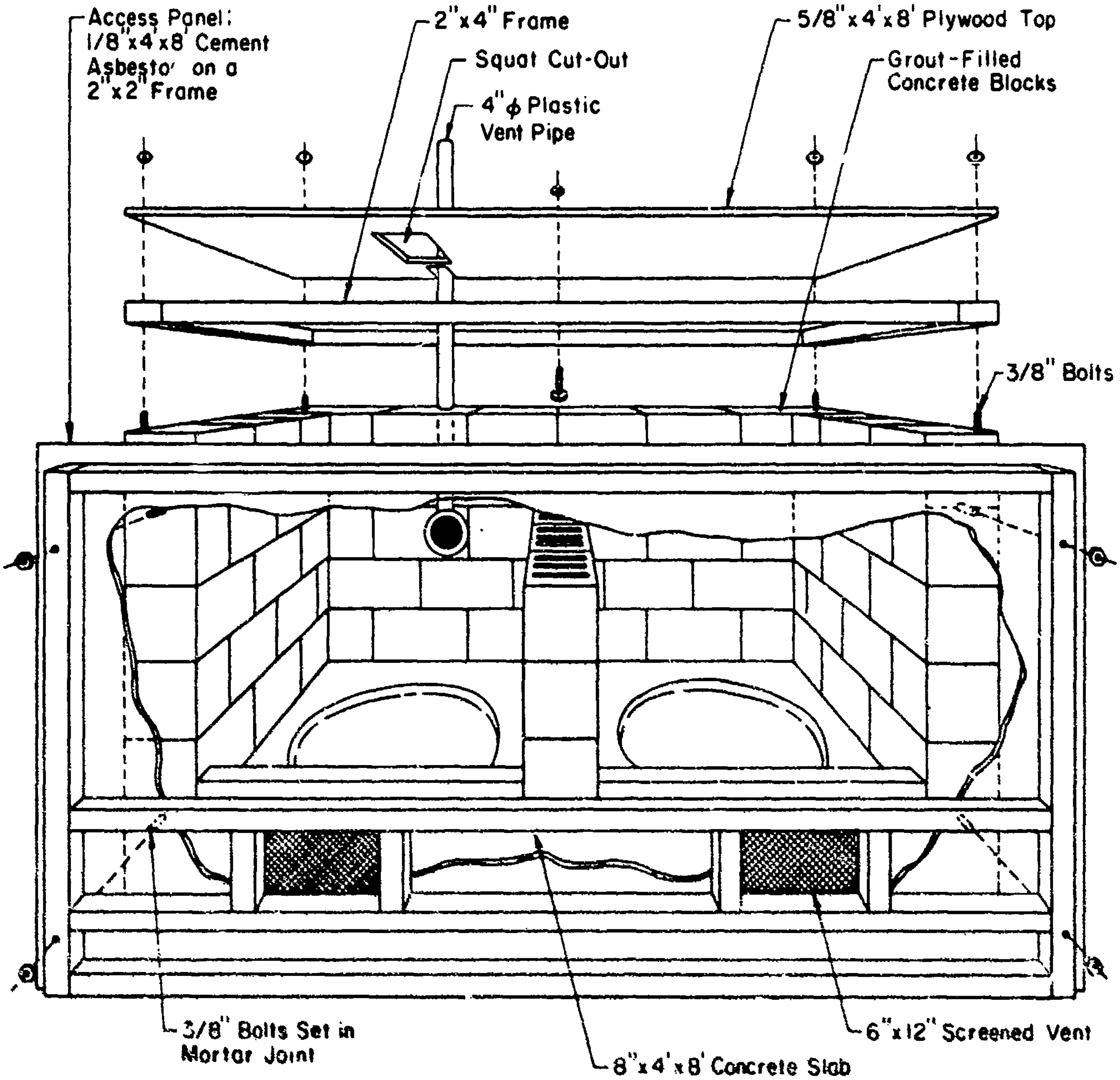


Figure A8. The Farallones composting privy. (Reprinted from C. H. Stoner, Goodbye to the Flush Toilet, permission granted by Rodale Press).

and retain the compost when the doors are opened. Construction plans for the Privy are available from the Farallones Institute, Berkeley, California.

In operation, the chamber below the seat or squat plate is first primed with 2 or 3 inches (51 to 76 mm) of sawdust and 4 to 5 inches (102 to 127 mm) of straw, spoilt hay, or grass clippings. After each use, a handful or cupful of some small-particled carbonaceous material (sawdust, leaves,

chopped straw mixture) is added to cover fresh feces. Once or twice a month, the back is opened in the early morning before fly activity, the pile inspected for the presence of vectors, and the nose test applied to determine objectionable odors. The pile is mixed and aerated using a pitchfork and flat shovel stored in the vault exclusively for this purpose, and necessary corrections are made for the moisture content.[23]

Summarizing the possible applications of the Farallones Privy, and composting toilets in general, Kroschel states that "there are, however, several questions concerning the small compost piles in a composting toilet. Do the small piles heat adequately; i.e., do they attain or exceed temperatures of 128°F (55°C) for significant periods of time?"[24]

Kroschel further says that "the conscientious attention and knowledge required puts it [maintaining the toilet] outside the realm of the average individual." He poses a key question: "Will persons be responsible enough to perform adequate mixing and maintenance to ensure adequate treatment and a safe and sanitary facility?"[25]

These questions must be addressed by the designers of alternative waste disposal systems; the answers will help determine the success of applied alternative waste disposal efforts.

In summary, Kroschel states that "the vault-type composting privy does not, however, seem applicable to high use rate conditions, particularly of a public access nature. The frequent handling required of raw feces from a large or diverse group coupled wit the potential for system overload or breakdown from neglect, mismanagement or abuse, make manually turned vault privies unsuitable for group-managed facilities."[26]

Survey of Composting Toilet Owners

Survey Details

A list of 22 public facilities now using one or more Clivus Multrum units was obtained from the manufacturer. Officials at 13 of the facilities were questioned during a comprehensive telephone survey.

1. Goldwater Lake Park, City of Prescott Parks and Recreation Department, P.O. Box 2059, Prescott, AZ, contact person: A. C. Wilson.

This park has four Clivus Multrum unit installed in 1979 by city personnel. During the peak season (May through August), about 200 to 250 persons use the unit daily. Mr. Wilson estimates an annual average of 30,000 uses.

[23] M. L. Kroschel.
[24] M. L. Kroschel.
[25] M. L. Kroschel.
[26] M. L. Kroschel.

Paper is added as a bulking agent; thus, a potential fire hazard exists, according to Mr. Wilson. Ventilation is aided by an AC fan. Passive solar heating is used to maintain compost chamber temperatures. The pile is mixed once a month.

The units are in a sensitive ecological area on the shoreline of a lake used for recreation. Water for handwashing is trucked in. A leaching field (no septic tank) is used for greywater disposal.

Officials are very pleased with the units, citing specifically low maintenance requirements.

2. Navajo National Monument, National Park Service, Tonalea, AZ, contact person: Steven Mille.

This facility has one Clivus Multrum unit, 5 or 6 years old. Usage is very light--three to four persons per day during the summer. The Clivus was selected due to low use; a conventional septic system was not needed. Mr. Miller says there is a slight odor problem because of inadequate air circulation--even though there is a fan. No other problems with the system were cited, although the odor could result from poor location.

3. San Joaquin Delta College, Department of Agriculture and Natural Resources, 5151 Pacific Avenue, Stockton, CA, contact person: D. Fritz.

This 5-year-old unit serves from one to 25 persons per day. No water or energy is available so the Clivus Multrum was selected. A wind turbine assists the natural ventilation process. Passive solar heating helps maintain adequate composting temperatures in the chamber. Mr. Fritz comments that officials are "very happy" with the system.

4. Wildlife Prairie Park, RR 1, Taylor Road, Hanna City, IL, contact person: M. Bjorklund.

This facility has five units in a visitor center on a 500-acre (200-hectare) educational and recreational facility. The units have been in full use since 1979, following a 2-year "experimental period." According to Ms. Bjorklund, average use is 120,000/yr. At peak periods, as many as 800 people may use the park during a single day.

Ms. Bjorklund expressed concern about the introduction of nonbiodegradable materials, such as plastics, into the units. She also mentioned that there had been two fires apparently from discarded cigarettes.

There were insect problems at first, but these were solved with no-pest strips. For long-term control, a regular maintenance program of mixing the pile and moistening with lukewarm water every 2 weeks was effective. Toilet seats are checked nightly to make sure they are closed.

Ms. Bjorklund says installation of each unit took about 2 man-days. Overall, she is very happy with the toilets. This facility was visited by CERL researchers in March of 1982. The units appeared to be operating well at that time with no objectionable odors and no visible vectors.

5. Maine Audubon Society, Gilsland Farms, 118 Old Rte. 1, Falmouth, ME, contact person: B. Ginn.

This facility has one Clivus Multrum, installed in 1975. This system was selected specifically to explore alternative technology. As in some other recreational systems, excess liquid build-up was a problem. This liquid is diverted to a leaching field, allowed by Maine officials to be "downsized." Insects and odors were encountered for an unspecified period of time. No problems regarding vandalism, fires, or excessive maintenance were cited; Mr. Ginn states that he is "quite happy overall with the unit." No information about the number of uses for the unit is available.

6. Blanford Nature Center of the City of Grand Rapids, 1715 Hillburn, N.W., Grand Rapids, MI, contact person: F. Essner.

Two Clivus Multrums were installed in 1980. Average use ranges from 50 to 200 persons per day; special events may draw up to 5000 persons to the area. Excess liquid due to heavy daytime use was reported; a dry well accommodates this excess.

The Clivus Multrum was selected because there were no sewer lines and soil conditions were too poor for a conventional subsurface disposal system. Highly fluctuating load conditions were also a factor. There have been occasional fly problems, but Mr. Essner states that he is "very pleased" with the performance of the units.

7. National Park Service, Rte. 1 NT 143 Headquarters, Administration Office, Tupelo, MS, contact person: D. Young.

This installation has one Clivus Multrum at a state highway rest area. As in other installations where transient use is predominant, excess liquid buildup was a problem. This was eventually solved by draining the liquid into a leaching field.

The Clivus Multrum was selected because it was cheaper than a well/flush toilet/subsurface system. Mr. Young estimates 10 average daily uses. The unit requires no special maintenance; Mr. Young states performance has been "good," with "no problems."

8. Hillside Outdoor Education Center, Gage Road, Brewster, NY, contact person: B. Summer.

Ms. Summer stated that one unit was installed in 1978. She estimates that the use is light and seasonal. No problems have been encountered, and no special maintenance is performed; Ms. Summer is "pleased" with the unit.

9. Hawk Mt. Sanctuary Association, RD #2, Kempton, PA, contact person: J. Brett.

This facility has three Clivus Multrum units. One is in the campground area and receives "minimal use." The other two are in the visitors' center and are used about 30,000 times per year (15,000 uses/yr/unit).

Excess liquid from the visitors' center units is drained into a flower bed. The short supply of water was the main reason for selecting the Clivus Multrum units, although regulatory problems involving waste holding tanks also were a factor. Occasional mixing of the pile has been necessary; no other extraordinary maintenance is performed.

Mr. Brett states that he is "very satisfied" with the performance of the units.

10. Kain Park, RD 22, Box 33, York, PA, contact person: G. Walker.

This facility, a lakefront park, has seven Clivus Mulrums that are 1 to 3 years old. Mr. Walker estimates average overall usage to be 2000/week in the summer, with little or no use in the winter.

A smoldering fire occurred in one unit, apparently caused by a discarded cigarette. There was no significant damage because the fire was discovered promptly. Excess liquid, a slight problem during the summer, is removed by a bucket. No other problems have been noted. Mr. Walker is "very pleased" with the performance of the units.

11. Scranton-Pocono Girl Scout Council, 333 Madison St., Scranton, PA, contact person: J. Gordon.

Nine units were installed at a Girl Scout Camp in the Pocono Mountains in 1980. Clivus Multrum units were selected because of the lack of water in winter, and dissatisfaction with the latrine systems used previously. Excess liquid buildup was encountered in one unit; a sump pump was installed to correct this. Insects were a nuisance in the first year; no-pest strips satisfactorily solved this problem. An aerated lagoon system is used to treat greywater from the camp. Ms. Gordon states that officials are very pleased with the units, and expect to install another in the near future.

12. Shelly Ridge Girl Scout Center, Manner Road, Springfield Township, PA, contact person: J. Hayford.

This facility, a camping and educational center, has two Clivus Multrum units (two seats each). Peak use is estimated to be 50/unit/day. The Clivus Multrum was selected because of the lack of water and public sewers at the site.

Odor problems during periods of high humidity have been noted. Also, there was a fly bloom lasting 2 or 3 days during the first summer of use. There have been problems with excess liquid. A trench drain handles the small amounts of greywater produced by handwashing.

No extra maintenance is performed; Ms. Hayford describes officials as "happy overall" with the units.

13. Parents, Inc., East Fairfield, VT, contact person: D. Schramm.

This facility is a cooperative elementary school run by the parents of the students. The Clivus Multrum toilet is 6 years old; it serves 23 persons/day during the school year. No problems of any kind were noted.

The unit was selected in part because of the parents' environmental awareness; in addition, a conventional subsurface sewage disposal system could not be installed because of soil conditions at the site.

Mr. Schramm states that the parents are "very happy" with the system. A user of the system in Hawaii has also expressed satisfaction with it.

Survey Results

The preceding observations cannot be considered conclusive because they are based on the opinions and subjective judgments of the persons contacted. Still, this information indicates that certain problems can develop during use of Clivus Multrum units:

1. Liquid buildup may be greater than that suggested by the manufacturer.

2. More maintenance than recommended by the manufacturer may be needed.

Other Types of Sewerless Systems

Several sewerless systems other than composting toilets have been developed:

1. Oil-flush systems -- oil is used as the flushing medium and recycled (Figure A9).

2. Incinerating toilets (Figure A10).

3. Vacuum systems (Figure A11).

4. Aerobic systems (Figure A12).

Of course, the method now used most widely is the conventional septic tank and leaching field.

The following brief descriptions of several representative systems are based on manufacturers' information.

Waterless Sanitation System

A product from Shasta Manufacturing, their Waterless Sanitation System, consists of a large solid can installed in the ground. A smaller perforated container is then installed recessed several inches from the outer shell. This allows liquids and solids to separate. The liquids evaporate and the solids dehydrate. Odorless operation is claimed. A key to successful operation is excellent ventilation around and through the system. Operation and maintenance is similar to a privy. Owner response to this system has been mixed.

Retail cost of units in 1983 ranged from $1171 to $2256 for 140 gal to 500 gal capacities. Buildings and installation are extra. Government discounts up to 16 percent are available.

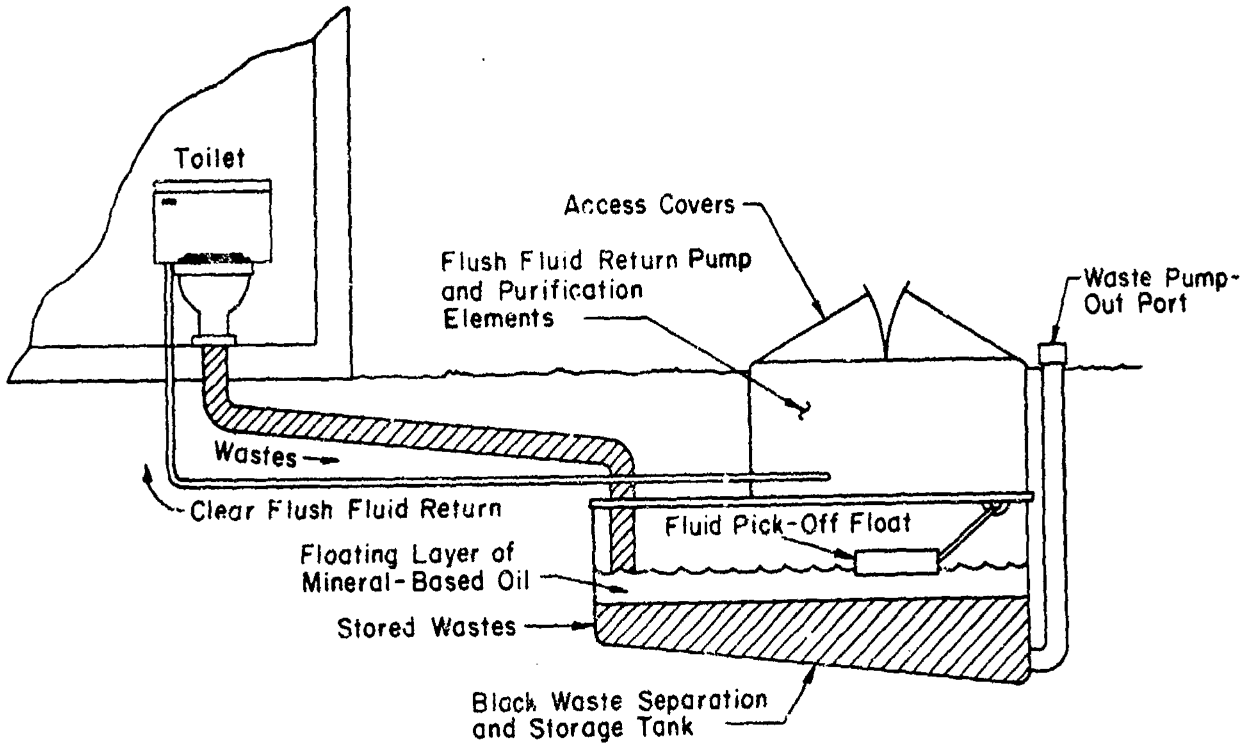


Figure A9. Oil-flush system. (Reprinted from C. H. Stoner, Goodbye to the Flush Toilet, permission granted by Rodale Press.)

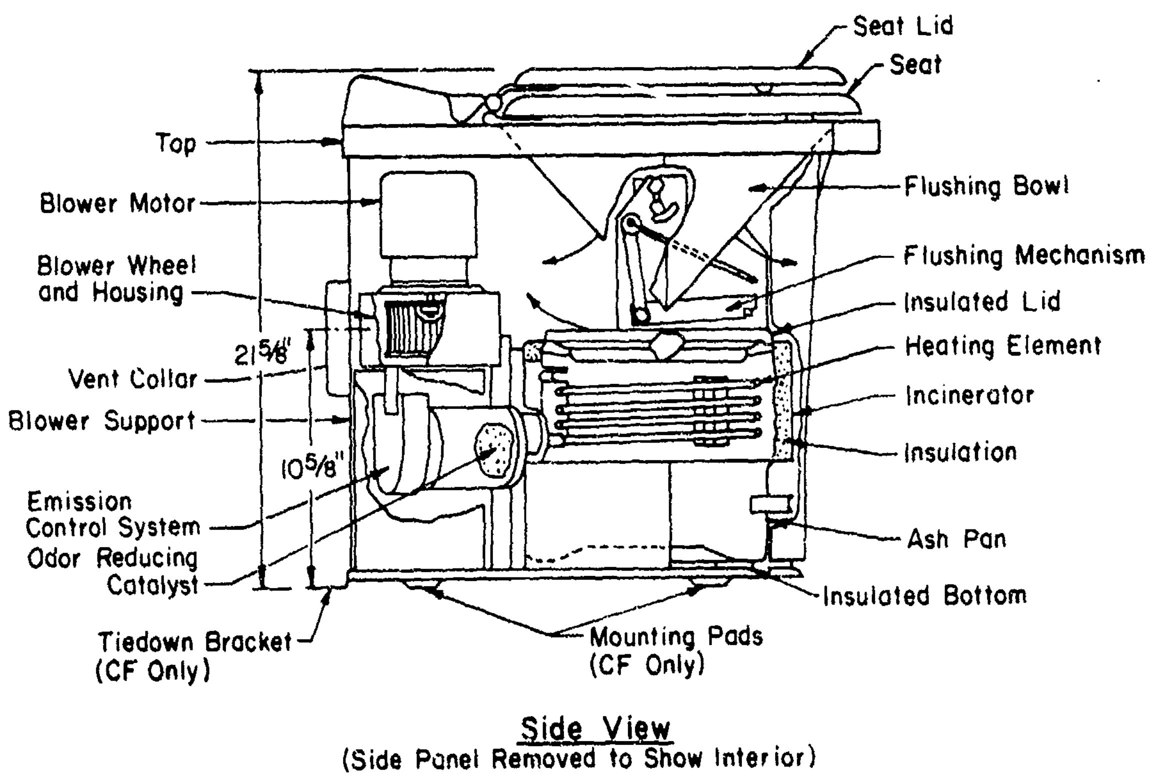


Figure A10. Incinerating toilet. (Reprinted from C. H. Stoner, Goodbye to the Flush Toilet, permission granted by Rodale Press.)

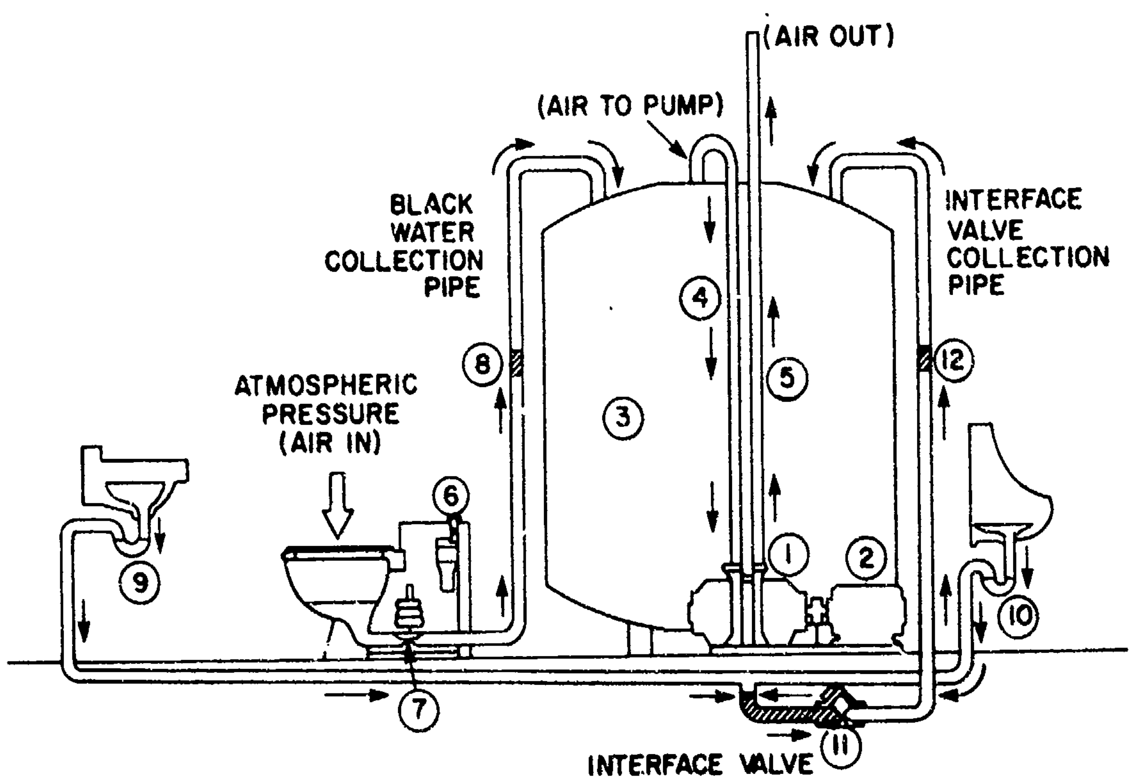


Figure All. Vacuum system. (Reprinted from C. H. Stoner, Goodbye to the Flush Toilet, permission granted by Rodale Press. Inc.)

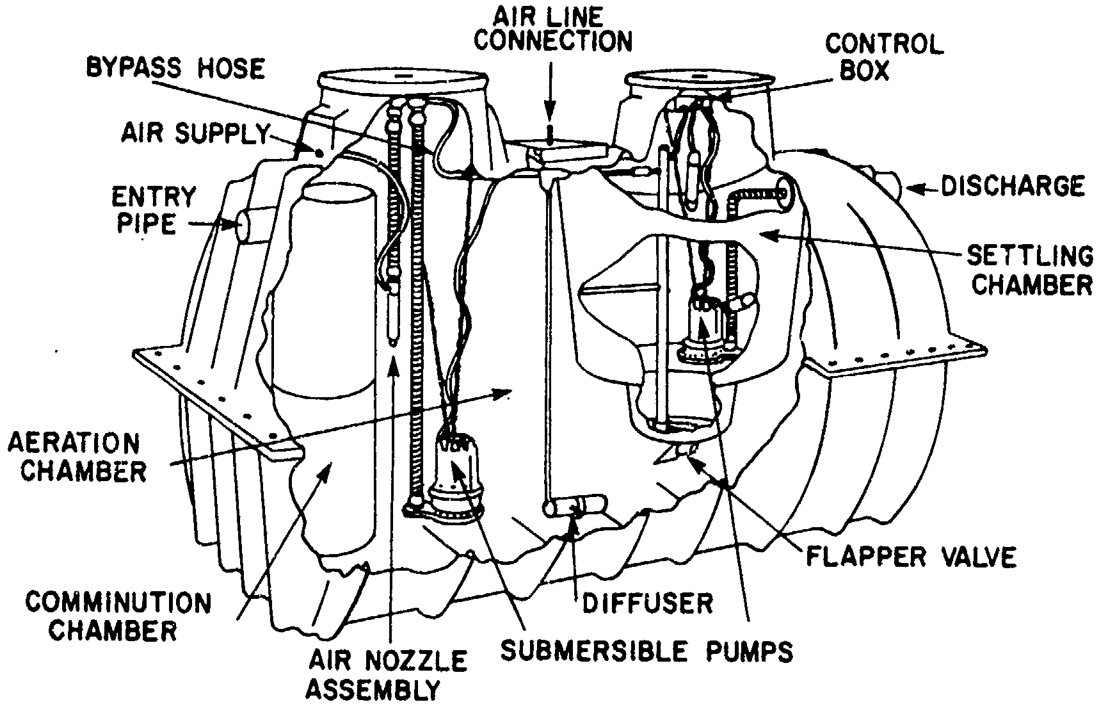


Figure A12. Aerobic system. (Reprinted from C. H. Stoner, Goodbye to the Flush Toilet, permission granted by Rodale Press, Inc.)

Microphor Low Flush Toilet

The Microphor Low Flush Toilet requires 2 qt (1.9 L) of water per flush. The flushing sequence is controlled by an air/water sequence valve. According to the manufacturer, action is initiated by pushing the flush handle, which turns the water on and opens the flapper in the bottom of the bowl. The bowl water and waste flow into a lower chamber. More water washes the empty bowl and flows to the lower chamber. After the washing action is complete, the flapper closes, water continues to run into the bowl (creating a seal), and fills the bowl to the normal level.

While the fresh water is filling the upper bowl, air enters the lower chamber; this pressurizes the chamber and moves the waste material into the common discharge line, which is normally vented. The air which has pressurized the secondary chamber is released harmlessly through the vent. The complete cycle takes about 12 seconds.

The requirement for compressed air makes this toilet more energy-intensive than conventional flush toilets, but this must be weighed against the advantage of water conservation and reduced water pollution.

The cost of the Microphor was not available.

On-Site Systems, Inc.

This is an add-on system used to improve existing septic systems, or to supplement septic systems which might not provide adequate treatment in new installations.

Effluent from a conventional septic tank is passed through a pea-gravel-and-sand filter, ozonated using an ozone generator, and passed through a biological activated carbon bed. The manufacturer claims that effluent can then be discharged to a leaching field, or re-used for toilet flushing. Other possible re-uses are being studied.

Cost of a home unit: $4550 (1981), assuming a minimum of 50 installations; includes installation and engineering.

Estimated annual operation and maintenance: $115/yr.

Bi-A-Robi Systems

The Bi-A-Robi System uses aeration equipment to modify existing septic systems so that they are aerobic. The market for these systems is primarily subsurface disposal systems that fail frequently. In addition to aeration equipment, Bi-A-Robi markets filtration systems, chlorination systems, and pressure dosing and pressure sewer equipment.

The manufacturer claims high levels of BOD and suspended solids reduction, and suitability in a variety of uses from 500 gpd to 60,000 (1890 Lpd to 227,125 Lpd) flow ranges. The complete system, according to the manufacturer, produces an effluent suitable for lawn watering or irrigating crops.

No specific information was provided on the cost of the system.

Multi-Flow Household Sewage Systems

The multi-flow system consists of a closed, package-type unit. It is designed to replace the conventional septic tank and is installed underground. Treated effluent is discharged to a conventional leaching field.

The unit features "living filters," or bacteria-covered fabric tubes for filtration and solids removal, and mechanical aeration to assure aerobic decomposition.

According to the manufacturer, waste matter flows into the central chamber. Air is drawn into the plant and dispersed near the bottom of the holding tank. Air bubbles travel upward and outward, transferring purifying oxygen to the system's contents. The rising air generates circulation within the system. The released oxygen promotes growth of the desired bacteria, which effectively break down organic solids.

Living filters hang suspended in the fluid. The filter surface supports additional bacteria for further cleansing. All fluid leaving the tank passes the walls of the filters, coming in direct contact with the bacteria.

The manufacturer claims there are no visible solids in the effluent, organic matter is reduced 95 percent, and the effluent is clear and odorless.

No specific information was provided on the cost of the system.

Incinolet Electric Toilet System

The Incinolet incinerating toilet is completely waterless; waxed-paper bowl liners are used to ensure maximum sanitation. Like other incinerating toilets, the Incinolet requires energy to burn off waste material. The Incinolet system can include a urinal and an all-electric configuration; the manufacturer claims the system can serve 12 persons per day.

According to the manufacturer, the incineration cycle is started when a radiant heater mounted above the waste is turned on. Urine is evaporated; solids are dried and fired, leaving only ash. In March 1982, the toilet unit cost $1695; the urinal system, $1795; and the combined system, $3495.

Incinomode

Little information was available on this incinerating toilet. According to the manufacturer, the incineration time varies considerably with the solids characteristics--e.g., volume and moisture content.

The recommended incineration cycle is 30 minutes; however, the unit can be re-used before cycle completion. The incineration cycle must be adjusted to allow for heavier-than-normal usage. The heater is rated at 2400 W at 230 V. Cost of the unit is $1299, FOB Sherman, TX.

Aqua-Sans Coil-Recycling System

This system uses oil as the flushing medium. Like other such systems, wastes and oil from flushing are transported to a separation tank where the sewage is separated by gravity.

According to the manufacturer, the fluid is filtered, purified, and re-used indefinitely. Concentrated waste from the Aqua-Sans separation tank is transferred to either a thermophilic digester/evaporator or a holding tank. Chlorine tablets control bacteria in the flush fluid. A coalescer screen, or separation tank, is used in the first stage to entrain moisture. Before reaching the reservoir, the oil passes through a filter bag, which retains minute particles of paper and fecal waste. Centrifugal pumps are used in the Aqua-Sans system and are pressure-switch controlled; an accumulator stores enough flush oil to meet peak flow demands. Carbon adsorption columns and clay packs remove mercaptans and other odor-causing substances and surfactants. This quickly separates the oil from the waste material.

The manufacturer claims the Aqua-Sans should be easy for unskilled personnel to maintain. Requirements for the system include periodic addition of chlorine tablets and replacement of filters. Maintenance periods depend on system capacity and the amount of usage. Power requirements are also a function of system capacity and usage. Peak power requirements for a system designed for 30 people on a 24-hour usage cycle would be about 10 kWh/day; this includes thermophilic digester/evaporator power.

No specific information was provided on the cost of the system.

Hadden Aerobic Filtration Spray Sewage System

This sophisticated waste treatment system consists of several steps designed to completely treat wastewater so that the final effluent can be used on-site for spray irrigation. The system consists of:

1. Primary digester tank
2. Secondary digester tank
3. Filter tank with primary and secondary filter
4. Holding tank
5. Water pump with pressure spray system
6. Chlorinator
7. Air pump to aerate primary filter and holding tank.

The manufacturer claims the system is simple to operate. Equipment is automatically operated and requires minimal storage space. No costs were provided.

Jet-o-Matic Water Saving System

The Jet-o-Matic water saving toilet systems are completely self-contained, outdoor recirculating toilets. A large holding vault under the unit can accommodate about 1000 uses before it must be pumped out. Capacity can be increased by connecting the units to an underground storage unit. A biodegradable chemical additive is automatically dispensed with each flush to provide odor control.

According to manufacturer's information, the unit operates as follows: When the foot pedal is depressed, the pin filter pump discharges about 1 gal (3.8 L) of filtered fluid into the bowl to flush the waste into the holding tank. The liquid is filtered on the reset portion of the flush cycle. When the toilet is flushed, the chemical dispensing pump receives a pressure pulse from the hydraulic activating mechanism, and the correct amount of chemical is automatically metered into the waste tank. This chemical is a proprietary product available from the manufacturer.

Jet also manufactures aeration equipment and pressure dosing equipment for existing subsurface sewage system rehabilitation. No costs were provided.

Thetford Waste Treatment Systems

This system incorporates a combination of modular treatment systems (including low-flush toilets), aerobic digestion chambers, membrane filters, activated carbon adsorbers, and ultraviolet/ozone disinfection. Combinations of modular equipment are used to achieve specific goals on a case-by-case basis.

The equipment manufacturer appears to be appealing to "marginal situations," where land disposal, effluent limitations, or limited water supply would not allow use of "conventional" sanitary facilities.

The Thetford "superinse" toilet, using 1 gal (3.8 L) per flush, can be used with conventional disposal systems. This toilet requires no energy for pumps, air compressors, or motors.

No cost was available for the units.

Greywater Disposal Systems

Greywater is wastewater that originates from households and that does not carry sewage. Typically, greywater comes from bathing, dishwashing, clothes washing, and kitchen/bathroom sinks. Given this description, greywater may seem relatively harmless and easily disposed of, but this is not so. In most cases, adequate greywater treatment and disposal must be provided when alternative sewage disposal systems are installed. According to Rockefeller, "greywater needs some form of pretreatment before use or disposal because the hair, grease and food particles in it would clog any distribution system."[27]

When a waterless toilet is used, it is estimated that the wastewater volume from a typical residence will be reduced 40 percent. In some cases, this allows development of land currently considered unacceptable, and is an important factor in the ultimate selection of the waterless toilet system.

When wastewater is composed only of greywater, it is important to consider in the design of a treatment/disposal system both the reduced volume of flow and the characteristics of the wastewater. According to Rockefeller, "Greywater is normally 15°F (8.3°C) warmer than sewage so that in cold climates one can put in distribution or leach lines closer to the soil's surface without the fear of freezing during winter. The advantage to having distribution lines near the soil's surface is so that plants and soil organisms, like worms, can use the water, nutrients, and organic matter."[28] This shallow burial also reduces construction and installation costs.

Stoner estimates that the volume of greywater produced ranges from 24 to 36 gal (91 to 136 L) per person per day, including the normal use of a washing machine and dishwasher in a residential setting. Stoner notes that "greywater is typically 30°F (16.7°C) hotter than combined sewage. Because this heat tends to keep grease liquified, pretreatment tanks should be designed to give off heat. Pretreatment tanks should be longer and narrower than conventional septic tanks to provide increased wall contact with the soil."[29]

Many areas of the State of Maine are not suitable either for central sewage treatment/collection systems or for conventional subsurface sewage disposal systems. Therefore, the State has explored alternative waste disposal systems in detail. Hoxie notes that "upon learning that a greywater disposal system must be installed, the impracticality of a dual water system usually influences [consumers'] final decision against a waterless toilet." Hoxie concludes that "less costly methods of greywater disposal must be developed to allow waterless toilets to become as economical as water closets."[30]

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[27] A. Rockefeller, "Private Profit and Public Waste: The Connection," Compost Science (September-October, 1976), pp 13-15.
[28] A. Rockefeller.
[29] C. H. Stoner.
[30] D. C. Hoxie, and W. W. Hincley, Factors Affecting Acceptance of Waterless Toilets--the Maine Experience (Maine Department of Human Services).

Subsurface disposal of greywater is most common now. When a waterless toilet is installed, the existing septic system can be retained for greywater disposal. Indeed, waterless toilets decrease hydraulic loading by 40 percent; this sometimes allows a chronically failing subsurface disposal system to perform satisfactorily without costly repairs. Stoner lists six ways to dispose of greywater below the soil surface: seepage pits (drywells), absorption trenches, seepage beds, evapo-transpiration beds, mounds, and leaching chambers. Stoner also provides diagrams of typical systems.)[31]

According to Stoner, greywater is free of the highly soluble chloride and nitrogen compounds from urine which are not treated well in soils. Thus, greywater is more amenable to subsurface disposal than is combined wastewater. Stoner states that "the primary causes of soil clogging in the leach field, the feces and toilet paper, are also eliminated. This reduction in pollutants also changes the nature of organic matter remaining in the greywater. Greywater contains about the same amount of oxygen-demanding compounds, and there is evidence to suggest that these compounds are greater and more easily stabilized than combined wastes. This means that treatment of greywater in soils is much more likely to be complete, thus reducing the possibility of ground water pollution and increasing its reuse potential"[32]

Since greywater lends itself to soil treatment, this wastewater might be treated and recycled rather than disposed of. According to Walker, "most greywater re-use is for landscape irrigation"; he goes on to note a case where "a group of homes filter greywater through a swimming pool filter to be reused for flushing toilets."[33]

Clivus Multrum is currently experimenting with a roughing filter for greywater pretreatment.

Rockefeller explains why roughing filters are more suitable than a septic tank for greywater pretreatment:

1. The resulting water is aerobic, rather than anaerobic, and is therefore better for plants and soils.

2. Leach lines are less susceptible to clogging.

In an integrated greywater disposal system being studied by Clivus Multrum, "Pre-treated greywater is passed through the floor of a greenhouse, serving to provide nutrients to plants and further purify the water."[34]

The concept of extensive greywater treatment systems is, of course, applicable primarily to selected domestic situations. Often, no such system is needed. Waterless restrooms at locations such as recreational areas and rest stations may have little or no greywater. In many instances, a simple drywell or leach bed may be more than adequate for drainage of lavatory sink

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[31] C. H. Stoner.

[32] C. H. Stoner.

[33] M. Walker and A. T. Ingham, "Wastewater Management for Rural Communities," Compost Science/Land Utilization (September-October, 1980), pp 35-38.

[34] A. Rockefeller.

wastes. Such simple systems are also usually adequate for drainage of excess liquid that accumulates in composting toilets.*

Regulations

The regulations of alternative waste disposal systems vary among states and local communities. In general, however, three areas may be affected:

1. Local or state plumbing codes. These currently require a flush toilet as a minimum requirement to meet the definition of "acceptable housing."

2. Compost disposal. In composting toilets, compost disposal may not be allowed or adequately addressed.

3. Greywater disposal.

Maine, Oregon, and California are now in the forefront in the evaluation of waterless toilets for homes. Other states are fairly receptive to "unusual applications," such as recreational areas, highway rest areas, and experimental, controlled locations.

Regulations on the use of waterless toilet systems are currently either nonexistent, incomplete, or outdated. Regulatory agencies at the state or local levels are ill-equipped to enact comprehensive policies because they do not have a sufficient database and effective means of control over a variety of situations.

In California, a few counties allow waterless toilets and greywater systems under an experimental permit, which requires a monitoring program by a field sanitarian or homeowner. While progressive, this program could be expensive, and has not been started by most states.

According to Leich, in California the Calaveras County Health Department is conducting an experimental program authorizing installation of several composting toilets and greywater disposal systems. Two large and two small toilets have already been installed under the supervision of a local firm which includes an ecologist, a licensed plumber, and a civil engineer.[35]

These projects, carried out at the county level, are experimental; their purpose is to provide data which can be used to draft a comprehensive policy to address alternative disposal methods.

Maine is also actively investigating alternative systems. Director of Human Services, Donald C. Hoxie, states that "Maine-approved types of waterless toilets are: open-pit privies, sealed vault privies, compost toilets, incinerator toilets, chemical toilets, and vacuum toilets. A permit is required only when a waterless toilet is installed without other plumbing fixtures." Concerning greywater disposal, Hoxie states, "To ensure that

*Appendix C lists manufacturers of on-site treatment systems.

[35] H. Leich, "Sewerless Sanitation," columns appearing in Compost Science/Land Utilization in 1977, 1979, 1980, and 1981.

greywater is disposed of properly, the Maine code requires that waterless toilets be accompanied by a septic tank and a disposal field approximately 65 percent of the size required for structures using a conventional plumbing system."[36]

Moreau says that Maine was "the first state to authorize compost toilets on a statewide basis and the first to discard the percolation test and require soil evaluation on a statewide basis." Regarding greywater disposal, Moreau notes, "The Maine state plumbing code requires the use of a greywater system if one uses a composting toilet and has running water under pressure." The system requires a septic tank and disposal field. The septic tank size may not be reduced; the drainage field may be reduced approximately 40 percent. The size of the drainage field ranges from 200 to 1000 sq ft (18.6 to 92.9m^2) depending on soil conditions, compared to 300 to 1440 sq ft (27.9 to 133.8 m^2) for a conventional system. However, Moreau says, "Maine does allow a modified greywater system without a septic tank if there is no running water under pressure and a waterless toilet is utilized." The disposal field area ranges from 25 to 170 sq ft (2.3 to 15.8 m^2), depending on soil conditions. This type of system normally would be used at locations such as a hunting camp or an infrequently used seasonal dwelling at a lake.[37]

The State of Washington issued a three-page set of guidelines in 1975, but prior approval for installing composting toilets must be obtained from the local health department. Provisions for greywater disposal must be made; reductions of 50 percent in septic tank volume and 40 percent in the size of the drain field are allowed.[38]

Stoner cites the following reasons for the delay in approval of alternative waste disposal systems:

> On the local level county sanitarians are reluctant to give approval for alternative systems because they are unfamiliar with anything other than the standard septic tank. They most likely will refuse to make a decision, regardless of how much information is presented to them, because they do not want to take the responsibility for possible failure. When approached about the use of a composting toilet and greywater reuse scheme, they may indicate that these would be a return to the more "primitive" pit-privy, and thus may be a step backwards in terms of public health protection.
>
> Public health officials also are reluctant to approve of any on-site system that requires knowledge or responsible action by the user. There can be no assurance that individual users will always maintain the toilet properly. Because the art of composting and an understanding of composting toilets are somewhat alien to

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[36] D. C. Hoxie and W. W. Hinckley.
[37] E. Moreau, "Maine's Perspective on Composting Toilets and Alternate Greywater System," Compost Science (July-August 1977), pp 18-19.
[38] H. Leich.

the way sanitary engineers and public health people think, they apparently figure that "ordinary" people cannot be trusted to understand.

Several tests on the health and safety aspects of composting systems have been done in the Scandinavian countries; only spot checks have been done in this country. This alone is not enough information to approve or disapprove of composting toilets. In areas where there are no other compelling reasons to switch their use, the health profession's conservatism wins out.

Public health departments do not always have the money or the manpower to monitor alternative systems. Even Maine, which has given broad approval to composting toilets, has only 24 staff people to cover the whole state. Because the technology of composting toilets is so young, the concern of health departments to oversee their operation and maintenance is understandable. When they allow several kinds of waterless toilets, in addition to the various new leach field designs, they incur greater costs in personnel training. For these reasons, it is cheaper and safer for states to give blanket approval to only those systems which their engineers learned in school -- those being the conventional systems.

Land use patterns will likely be altered by approval of alternative on-site methods, if strict land use planning is not enforced. A major point of institutional resistance relates to the scattered development of rural areas. Generally, a septic permit requires adequate soils with suitable drainage, and consequently residential development is most often on the best agricultural lands. If waterless toilets were suddenly found acceptable, people could settle virtually anywhere they wanted. Planners are distressed at the thought that people could live at distances from fire, police, transportation, electric and school services. The cost of providing these services to such scattered developments would be considerable.

Many states hinge their skepticism toward composting toilets on the basis of the added cost which is seen as duplicative of the costs of septic systems. Since greywater has to be treated and disposed of anyway, the reasoning continues, the required septic system would greatly reduce the need for a waterless toilet. The Commonwealth of Virginia requires that one solution be found to the "Total Problem," and the design standards are set so that any dwelling with pressurized water must have a full-sized leach field, regardless of what volume of wastewaters are generated.

Most states have reluctantly accepted the notion of a composting toilet, but are satisfied that their use will generally be limited in rural areas to replace the privy, or in recreational developments. In general there is a requirement that if a municipal sewerage disposal facility is nearby, then alternatives are not allowed, except in Washington and New Mexico. In those states, discharge of greywater into an existing sewer is allowed even in cities, as long as the human wastes are disposed of in a safe manner.[39]

Since requirements vary widely from state to state, prospective owners of composting toilets should contact the appropriate state or county regulatory agency for information.

[39]C. H. Stoner.

APPENDIX B:

SEWERLESS WASTEWATER SYSTEM MANUFACTURERS

This is not a comprehensive list of all the alternatives to flush toilets and septic tanks and of all the water-conserving hardware on the market today. For the most current information about such equipment, plumbing supply houses and magazine classifieds should be checked.

Aerobic Systems

Aquarobic Home Sewage Cromaglass Single Home
Treatment System Aerobic Wastewater
P.O. Box 1150 Treatment System
Penetanguishene, Ontario Cromaglass Corporation
Canada L0K 1P0 Williamsport, PA 17701

BI-A-ROBI Systems Jet Plant
Box 133 Jet Aeration Co.
Hamlin, PA 18427 750 Alpha Drive
Cleveland, OH 44140
BIODISC
Ames Croste Mills & Limited The Mini-Plant
105 Brisbane Rd. Eastern Environmental Controls, Inc.
Downsview, Ontario Box 475
Canada M3J 2K7 Chestertown, MD 21620

Biological Toilets

Bio-Flo
Pure Way Corporation
301 42nd Ave.
East Moline, IL 61244

Composting Toilets

Bio Loo Mull-Toa (Soddy Potty and
Clivus Multrum USA, Inc. Bio-Let)
14A Eliot St. Future Eco Systems Ltd.
Cambridge, MA 02138 680 Dennison Street
Canada L3R TC1

or

Bio Toilet (A, M, and 75)   Ecos Inc.
Bio-Systems Toilets Corp. Ltd.   21 Imrie Road
255 Gladstone St. Boston, MA 02134
Hawkesbury, Ontario
Canada K6A 2G8   Soddy Potty #2
ASI Environmental Division
Clivus Multrum   2 Industrial Parkway
Clivus Multrum USA, Inc.   Woburn, MA 01801
14A Eliot St.
Cambridge, MA 02138   Toa Throne
Enviroscope, Inc.
Mullbank (Ecolet) P.O. Box 752
Recreation Ecology Conservation   Corona del Mar, CA 92625
of United States, Inc.
9800 West Bluemound Rd.
Milwaukee, WI 53226

Low-Flush Toilets

Conserver   Radcliffe Water Miser
Silhouette II Conserver   Crane Co.
Briggs   300 Park Avenue
P.O. Box 22622   New York, NY 10022
Tampa, FL 33622

Water Saver Cadet Toilet
Emblem Water-Saving Water   American Standard
Closet   P.O. Box 2003
Eljer Plumbingware   New Brunswick, NJ 08403
Wallace Murray Corporation
3 Gateway Center   Wellworth Water-Guard
Pittsburgh, PA 15222   Toilet
Kohler Co.
LF 210 Low-Flush Ceramic   Kohler, WI 53044
Toilet and LF 310 Stainless
Steel Toilet
Microphor
P.O. Box 490
Willits, CA 95490

Greywater Treatment Systems

Minipur System   Sarmax System
Enviroscope, Inc.   Sar Industries, Inc.
P.O. Box 752   2207 South Colby Ave.
Corona del Mar, CA 92625   Los Angeles, CA 90064

"Magic Flush"
Monogram Industries, Inc.
P.O. Box 92545
Los Angeles, CA 90009

Recycling Systems

Cycle-Let Incinomode
Thetford Corporation Incinomode Sales Company
P.O. Box 1285 P.O. Box 879
Ann Arbor, MI 48106 Sherman, TX 75090

Incinolet Thiokol Chemical Zero
Research Products Blankenship Discharge Waste
2639 Andjon Treatment System
Dallas, TX 75220 Thiokol/Wasatch Division
P.O. Box 524
Brigham City, UT 84302

Oil-Flush Toilets

Aqua-Sans Trickle Filter
Space Division, Chrysler Corporation Clivus Multrum USA, Inc.
P.O. Box 29200 14A Eliot Street
New Orleans, LA 70189 Cambridge, MA 02138

Incinerating Systems

A-C Storburn Destroilet
Lake Geneva A&C Corp. LaMere Industries, Inc.
Box 89 200 Elkhorn Road Walworth, WI 53184
Williams Bay, WI 53191
and in Canada:
Storburn Limited Multi-Flo
Box 3368 Station "C" Multi-Flo, Inc.
Hamilton, Ontario 500 Webster St.
Canada L8H 7L4 Dayton, OH 45401

Vacuum Toilet Systems

Airvac Vacu-Flush System
P.O. Box 508 Mansfield Sanitary, Inc.
Rochester, IN 46975 150 First St.
Perrysville, OH 44864
Envirovac
Colt Industries, Waster and Waste
Management Operation
701 Lawton Ave.
Beloit, WI 53511

APPENDIX C:

MANUFACTURERS OF ON-SITE SEWAGE DISPOSAL SYSTEMS

A.S. Andstor & Co.
Kristian IV gt. 12
Oslo, Norway

Aquarobic USA, Ltd.
John Hanson Building, Suite 307
7610 Pennsylvania Ave., N.W.
Washington, DC 20028

Aqua-Sans
Chrysler Corp., Space Division
Environmental Systems
P.O. Box 29200
New Orleans, LA 70189

ASI Environmental Division
2 Industrial Parkway
Woburn, MA 01801

BI-A-ROBI Systems
Box 133
Hamlin, PA 18427

Biolet Corporation
P.O. Box 645
Beatrice, NB 68310

Bio Recycler Co.
5308 Emerald Drive
Sykesville, MD 21784

Bio-Systems Toilet Corp. Ltd.
225 Gladstone Street
Hawkesbury, Ontario
Canada K6A 2G8

Brandywine Steel Corp.
P.O. Box 271
Downington, PA 19335

Clivus Multrum USA, Inc.
14A Eliot Street
Cambridge, MA 02138

Colt Industries
Water and Waste Management Operation
701 Lawton Avenue
Beloit, WI 53511

Cromaglass Corp.
Box 3215
Williamsport, PA 17701

Demco, Inc
829 S.E. 29th Street
Oklahoma City, OK 73109

Eastern Environmental Control Inc.
Box 475
Chestertown, MD 21620

Ecos, Inc.
21 Imrie Road
Boston, MA 02134

Environmental Services, Inc.
Granite and West Streets
Midland Park, NJ 07432

Flygt Div. of IT&T
129 Glover Avenue
Norwalk, CT 06856

Future Eco-Systems Ltd.
680 Demson Street
Markham, Ontario
Canada I3R 1C1

Incinimode Sales Company
P.O. Box 879
Sherman, TX 75090

Jet Aeration Company
750 Alphs Drive
Cleveland, OH 44143

Koehler-Dayton Division
P.O. Box 309
New Britain, CT 06050

Lake Geneva A&C Corp.
200 Elkhorn Road, Box 799
Williams Bay, WI 53191

Lamere Industries, Inc.
227 N. Main Street
Walworth, WI 53184

Marubeni America Corp.
200 Park Avenue
New York, NY 10017

Microphor, Inc.
P.O. Box 490
Willits, CA 95490

Monogram Sanitation
Products, Inc.
1945 E. 223rd Street
Long Beach, CA 90810

Multi-Flo, Inc.
500 Webster Street
Dayton, OH 45401

Nayadic Sciences, Inc.
Uwchland, PA 19480

Pure Cycle Corp.
P.O. Box 671
1668 Valtec Lane
Boulder, CO 80301

Pure Way Corp.
301 42nd Avenue
East Moline, IL 61244

Recreation Ecology
Conservation of U.S., Inc.
9800 W. Bluemound Road
Milwaukee, WI 53226

Research Products
Blankenship
2639 Andjon
Dallas, TX 75220

Restroom Facilities Corp.
560 E. Plumb Lane
Reno, NV 89502

Santerra Industries, Ltd.
1081 Alness Street
Downsview, Ontario
Canada M3J 2J1

Sarmax Corporation
27762 Camino Capistrano
Laguna Niguel, CA 92677

Shasta Manufacturing, Inc.
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APPENDIX D:

VAULT TOILETS: DESIGN AND MAINTENANCE CONSIDERATIONS

(This material is excerpted from a February 1976 U.S. Forest Service publication, Vault Toilets...Design and Maintenance Considerations.)

INTRODUCTION

Vault toilet designs present numerous maintenance and operational challenges. Some of the problems that exist when a vault toilet is serviced at a Forest Service site, and some design and maintenance considerations that may lessen these problems, are presented herein.

DESIGN AND MAINTENANCE CONSIDERATIONS

Is the Pumper Properly Equipped?

Many commercial sewage pumpers that are engaged by the Forest Service are equipped to pump septic tanks and industrial sumps, and have 2-1/2-in. hard rubber suction hoses that taper to 2-in. metal ends. An on-off suction valve is often located at the truck. This equipment could use two operators. When the hose becomes clogged, an operator standing at the truck must turn the suction line off so another operator at the vault can clear the end of the hose.

Some commercial sewage pumpers come equipped with 4-in. hoses. The 4-in. opening facilitates removal of cans, bottles, and fairly large rags if the pumper is using the vacuum principle. If the cans, bottles, and other debris are pumped from the vault into the truck tank, the pumper operator has a disposal problem. Sewage treatment plants will usually not accept this organic material.

A rake, a hoe, and a garbage can lined with a plastic bag (waste container) should be available in the immediate vicinity of the pumping operation. The rake should have a minimum of four tines about 4-in. long for removing the miscellaneous debris. The hoe is needed to stir the vault contents immediately before pumping, and the waste container is needed for the miscellaneous material removed with the rake.

If a waste container is located immediately adjacent to the entrance of the toilet building for public use, it may serve to reduce the amount of the debris the toilet users throw into the vault. This will lessen the debris that has to be removed during pumping operations.

Recommendations

The open end of the suction hose should be a minimum of 3 in., and preferably 4 in.; also, the hose should be the same size.

If the commercial pumper operator discharges the waste at a treatment plant and has no means to dispose of cans and bottles and other debris after they are in the truck tank, as much as possible of the miscellaneous debris should be removed before vault pumping begins. The remainder of the debris can be removed after pumping.

How Should The Vault Access Cover be Shaped and Where Should it be Located?

Access covers at existing vault toilets vary in shape, size, and location. Some of the designs and problems are examined below.

Pumping Through the Toilet Seat Riser Hole (With Riser Removed)

Toilet building compartments are usually quite small. It is difficult for the pumper operator to maneuver when using a hose, rake, or hoe in this small area. When the hose becomes clogged, the operator must lift the hose from the vault and, after turning off the suction valve at the truck, must place his foot on the object clogging the hose and lift the hose. At this point, the sewage immediately behind the clog pours over the floor surface and the operator's foot. Also, during this process the hose usually is rubbed against the wall depositing fecal matter and debris. By the time the operator finishes a very normal pump out, the floors and lower walls are heavily contaminated. If the floors or walls are porous, odors remain for a long time; and, people, especially those barefoot, are subjected to a very unsanitary condition. A typical vault toilet riser hole is approximately 18 x 22-in. If it is necessary to enter the vault the space will only accommodate a small person.

Pumping Through an Access Cover Located in the Front Entrance Way

This location produces the same results as stated in the previous section. Most front entrance ways are unsealed concrete and very porous. Having the access cover in this location places it at opposite ends of the vault tank from the concentrated waste. This makes it difficult to remove the concentrated waste. Some buildings have a privacy screen in front of the entrance doors. Trying to maneuver between the building and privacy screen with long-handle tools is awkward.

If the cover is not gasketed, odors rising around the cover can be offensive to the toilet user. During the normal building cleaning process, dirt and debris are either swept or washed out the front door and end up on the access cover. Some of this contaminated material may fill the space around the access cover and remain as a source of odor. When a gasketed cover is opened to clean the vault, the gasket area has to be thoroughly cleaned if the cover is to reseal and prevent odors. Even if the access cover is of adequate size for easy entry the location presents too many problems.

Recommendations

The access cover should have a minimum dimension of 24-in. and be located immediately to the rear or side of the building, whichever is closer to the vault toilet riser. Generally, the flow of traffic is not past the rear of

the building; therefore, if the areas immediately adjacent to the access cover did become contaminated, few people would be exposed to it.

The cover should be round because it is impossible to drop a round cover through the opening. If the cover is square or rectangular it should be hinged so that the cover rises toward the building. The cover should be locked for public safety.

How Deep Should the Vault be?

Existing vaults vary from 4 to 10 ft deep. The difficulty of cleaning a vault increases with depth.

Most commercial pumpers use flexible hose at the suction end of the pumping line. As the depth of the vault increases, it becomes more difficult to maneuver the hose. Consequently, the hose may be dropped in and remain in one area. Within the first few minutes most, if not all, of the available water portion of the waste is removed. If, at this time, there is no additional water available, the pumper can do little more than remove a portion of the sludge by moving the hose (with difficulty) within the vault.

Removing large objects (for example, 30- to 70-lb rocks) from deep vaults is difficult because the leverage point is too far from the object, i.e., one is attempting to work from the outside of the vault. The best way to remove large objects is to enter the vault and remove them by hand. The deeper the vault, the more reluctant the pumper operator is to enter it; also, the deeper the vault, the greater the chance of deoxygenation. Therefore, precautions should be taken to assure that the operator has sufficient oxygen when he is in the vault.

If the vault is 6 to 8 ft deep, the pumper operator must have a rake at least 7 to 9 ft long to remove miscellaneous debris. It is difficult to balance this debris while lifting it out of such a deep vault. The difficulty increases when the pumper operator is confined within a building compartment or in the front entrance area.

Recommendations

The vault should be about 4 ft deep. This will allow the pumper operator to easily remove the debris, to easily maneuver his hose for greater sludge removal and, if it is necessary for the operator to enter the vault to remove a large object, it will not be too unpleasant. If the vault is less than 4 ft deep the waste quickly builds up close to the toilet user and causes a visual problem.

What Volume Should the Vault be?

Vault capacities vary from 55 to 1,200 gal.

Typically, vault pumping contracts are initiated on a Forest or District. An inspection is made of the vault toilets to determine which should be

pumped. During the inspection the depth of the waste below the floor line is a major factor in selecting vaults for pumping. In many cases the inspector has never seen the true bottom of the vault and there is no list immediately available of how deep the various vaults are. Some vaults have not been pumped for many years.

If a vault does not get thoroughly cleaned each year, miscellaneous debris builds up and within a year or so the debris bridges the waste. Then the vault may be difficult to clean and often only gets cleaned down to a debris level. There may still be a few feet of fecal matter left but the accumulation of debris prevents further normal pumping procedures.

Vault pumping contracts vary in content according to local private or methods employed. The three most common methods of contracting are:

1. Vault basis: the contractor receives the same compensation regardless of size.

2. Hourly basis: the contractor is compensated from the time of departure from his place of business until his return to point of origin.

3. Gallon basis: the contractor is compensated for the number of gallons pumped from each vault.

If the contractor receives the same compensation for each vault regardless of size, then it would not be cost-effective to limit the size of a vault in a heavily used recreation area that might require more than one pumping per season.

Recommendations

Each new vault toilet proposal should be analyzed and the vault size determined based on the use in the area. The depth of the vault should not exceed 4 ft and, in most cases, a capacity of 500 gal will be sufficient. Each vault should be thoroughly cleaned each year.

When a 1,000-gal vault only receives 250 gal of waste, it is more difficult to clean because the waste is dispersed.

How Should Vault Waste be Removed?

The operator has two options:

1. Remove cans, bottles, rags, clothing and other scellaneous debris by using a rake or hoe prior to pumping and place it in waste containers. The plastic bag containing the debris can then be hauled away as solid waste. After removing the debris, use a 3 to 4-in. hose to remove the waste. A small hose, 2 to 2-1/2 in., is easier to handle, but is more susceptible to becoming clogged.

2. Use a 4-in. or larger hose to remove the waste and miscellaneous debris.

Many treatment plant operators will not accept this debris so it must be removed during the pumper discharge process. Debris such as logs and rocks cannot be pumped and must be removed by hand.

The Forest Service has designed some vault waste dump stations as concrete manholes with slanted or horizontal bar screens to remove the miscellaneous debris. Varying degrees of success have been achieved with this method. If the bars are too far apart, then plastic bags and large rags pass through. In aerated lagoons these items jam the aerator impellers. If the bars are too close together the screen has to be cleaned every few minutes.

Recommendations

Regardless of how the vault is pumped and cleaned, the miscellaneous debris has to be handled. Using the proper tools, it is easier to remove the debris prior to pumping. In order to remove debris from various depth existing vaults, the rakes and hoes should have adjustable handles. The waste should be pumped using 3 to 4-in. hoses.

When the vault is only 4-ft deep, excavation problems, water table problems, and earth pressure against the vault sides are reduced. Concrete block can be used as a support for the Hypalon (synthetic rubber) liner. (Hypalon has been recommended by the DuPont national representative as being the best synthetic rubber product for vault toilet liners.) By using 45-mil nylon-reinforced Hypalon, only a sand bottom is necessary for the liner. Pour 3 to 4 in. of concrete into the liner to prevent puncturing of the liner by glass, rocks, logs and pumper hoses. More concrete may be necessary to prevent uplift from a high water table. The liner can be attached to the upper concrete block wall by 1 x 3-in. treated boards using screws and lead inserts. Metal grommets are evenly placed around the top lip of the vault liner during factory fabrication.

The floor surface of the vault should be sloped 1-in./ft toward the outside access cover; then, the slope stops 6 in. from the Hypalon support and becomes a flat level plane the last 6 in. The flat surface will allow the sewage suction hose to get close to the bottom for more effective removal. An alternative to the Hypalon liner is a rigid cross-linked polyethylene container. It is not necessary to pour concrete into the container. Only a sand bedding is needed under the container in high water table areas. The container should be secured to the concrete block walls as previously described for the Hypalon liner. If a concrete slab were placed over the top of the container (as a floor slab), then no securing would be necessary. The cross-linked polyethylene container can be designed to be buried without additional support.

Should Vaults be Cleaned After Pumping, and if so, How?

When the level of waste is lowered by pumping, small waste particles will adhere to the sides of the vault even if the walls are cross-linked polyethylene or synthetic rubber. These small particles will generate a considerable odor as oxygen is made available for the bacteria to begin decomposition. The particles will soon dry and stick to the wall surface. During the next

pumping more particles will adhere to the dried particles already on the wall. Each cycle will cause more buildup of waste on the wall. Present concrete vaults and concrete block vaults are impossible to thoroughly clean because they absorb odors. Also, concrete has a tendency to crack allowing the liquid to seep away making the contents difficult to pump.

Recommendations

The vault walls should be hosed down with a pressure hose and, if possible, scrubbed with a long-handled brush. The extra water should then be pumped out.

If the vault floors slope 1-in. per ft, the washdown water will flow to the low end making it easier to remove. When as much waste and washdown water as possible is removed, add enough fresh water to cover the bottom floor surface of the vault.

In a vault sloped 1-in. per ft having the dimensions 5-ft long, 4-ft deep, and 3-1/2-ft wide (approximately 500 gal), it will take about 30 gal to cover the entire bottom surface. This added water will help dilute the remaining waste and aid in preventing the fecal matter from forming a cone.

What About Vault Toilet Building Floor Surfaces?

The floor surfaces in existing vault toilet buildings range from particle board to concrete. These surfaces harbor bacteria, creating unpleasant odors and unsanitary conditions. A Project Record, "Comfort Station Interior Finishes," is available from the San Dimas Equipment Development Center.

All floor surfaces should be slightly sloped to the front and be completely sealed, so that fecal and urine waste, causing odors and an unsanitary condition, cannot be absorbed by the flooring material.

Should Chemicals be used in Odor Control of Vaults?

There are approximately 200 manufacturers of odor control chemicals. Chemicals are used mostly to aid in odor control of poorly vented vault toilets. When using chemicals, consider where the waste will be taken and whether chemical addition will hinder treatment of the waste. About 3,000 gal of vault waste containing odor control chemicals has been known to sterilize a 110,000-gal aerated lagoon.

Recommendations

In general, chemicals should not be used. Analyze the venting system of the building. If it is impossible to reduce odors by improving venting, consider using only formaldehyde-base chemicals or space deodorants, and do not exceed recommended use. Formaldehyde will biodegrade with sufficient dilution. Odors also rise from porous walls and floors in poorly maintained and

older buildings. Building interiors should be cleaned often with a disinfectant deodorant-type cleaner.

SUMMARY

A vault designed to reduce maintenance and odor should have the following:

1. A 24-in. minimum diameter round access cover located immediately behind or to the side of the building.

2. A maximum capacity of 500 gal unless, after analysis, it is determined that a larger capacity is warranted.

3. A depth of approximately 4 ft.

4. A vault bottom sloped 1 in per ft toward the access cover, except the last 6 in. should not be sloped but be a flat level plane.

5. An impervious liner to prevent seepage (in or out), and to make it easy to clean after pumping (45-mil reinforced Hypalon or cross-linked polyethylene is recommended). After cleaning, enough water should be added to completely cover the bottom of the vault to help dilute the waste and aid in preventing the fecal matter from forming a cone.

6. No odor-control chemicals if they are going to hinder the final treatment process; proper venting will take care of most odor problems.

7. All walls and floor surfaces in the building use area properly sealed and the floor sloped to the front for easier cleaning.

8. Waste containers permanently located immediately adjacent to toilet entrances.

The present cost of a 45-mil nylon-reinforced Hypalon liner of 500-gal capacity is approximately $120. The present cost of the cross-linked polyethylene container of 500-gal capacity is approximately $200. The future design of the container to be buried without support is projected to be $300. More detailed information on the procurement of these or larger capacity liners and containers can be obtained through the following manufacturers.

<u>Hypalon Liner</u>

Burke Rubber Co.
2250 S. Tenth Street
San Jose, CA 85112
Telephone: 408/297-3500

<u>Polyethylene Container</u>

Hollowform, Inc.
6345 Variel Avenue
Woodland Hills, CA
Telephone: 213/884-0949

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MDW
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MTMC
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